The A. & M. College of Texas

Department of OCEANOGRAPHY AND METEOROLOGY

THE PETROLOGY AND PETROGRAPHY OF SEDIMENTS FROM THE SIGSBEE BLANKET, YUCATAN SHELF, MEXICO

by

Joseph D. Williams

Office of Naval Research
Contract Nonr 2119(04)
A&M Project 286(A)

National Science Foundation
Grant G-24892
A&M Project 323

American Petroleum Institute
Project 63
A&M Project 287A

Reference 63-12T

Research Conducted through the
Texas A. & M. Research Foundation
COLLEGE STATION, TEXAS

THE AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
Department of Oceanography and Meteorology
College Station, Texas

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Projects 286(A), 287(A), and 323, Reference 63-12T

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Project 286(A) was supported by the Office of Naval Research under Contract Nonr 2119(04), Project 287(A) by the American Petroleum Institute under Project 63, and Project 323 by the National Science Foundation under grant number G-24892.

May 1963

INTRODUCTORY STATEMENT

The following report is based upon a thesis submitted by Mr. Joseph D. Williams in partial fulfillment of the requirements for a Master of Science degree in Geological Oceanography at the A. and M. College of Texas. The work was supported by Office of Naval Research contract number Nonr 2119(04) (Project Supervisor - Dale F. Leipper) and American Petroleum Institute project number 63 (Project Supervisor - Louis S. Kornicker). Ship operation was supported in part by National Science Foundation grant number G-24892 (Project Supervisor - Hugh J. McLellan). The research was conducted under the immediate supervision of Dr. Brian W. Logan, chairman of Mr. Williams' thesis committee. Other members of the committee were Dr. Louis S. Kornicker, Dr. Hugh J. McLellan, and Dr. W. S. McCulley.

Acknowledgments are due Mr. James L. Harding and Mr. Wayne M. Ahr, who are conducting thesis research in the same area, for making some of their results available, and to Mrs. La Nelda Bullard for secretarial services and assistance in statistical computations.

Louis S. Kornicker
Project Supervisor

ABSTRACT

The Sigsbee blanket is a lithologically distinct unit of the Holocene to Recent sediment mantle which covers the outer shelf and continental slope provinces of the Yucatan Shelf. A detailed petrographic study has revealed that the unit is composed dominantly of planktonic lutite with varying percentages of calcareous pellets, ooids lithic fragments, non-skeletal aggregates, algal fragments, tests of benthonic foraminifera and fragments of shells and skeletons of mollusks, coral, bryozoans and echinoids. The landward boundary of the unit is a gradation with the adjacent skeletal calcarenites that occur on the inner shelf; the seaward boundary may extend as far as the Sigsbee Deep. The lower contact grades from an unconformity on the upper-outer shelf and outer shelf terrace, to a mild disconformity on the outer shelf margin and finally to a conformable contact near the shelf-slope break. The upper boundary of the unit is the sediment-water interface. Terraces mark the outer shelf between -450 feet to -300 feet and between -170 feet and -210 feet. In the depth zone between the 170 foot and 300 foot isobaths the substratum is calcite-cemented limestones (Wisconsin in age). The Sigsbee blanket has been deposited under the conditions of transgression in post-glacial time and the effect of the transgression is reflected by constituent and facies variation. The most striking variation is in the relative percentages of planktonic tests and shells, calcareous pellets and ooids. Four facies are contained in the Sigsbee blanket, these are:

1) ooid-pellet calcarenite facies
2) silty, planktonic, ooid-pellet calcarenite facies
3) silty, planktonic, pellet calcarenite facies
4) planktonic calcilutite facies.

The facies are the result of the deposition of an extensive shallow-water marine shoreline-to-nearshore sediment type that has been contaminated by the oceanic, planktonic lutite. Post-depositional processes, animal burrowing and occasional stirring by hurricane waves, have given the unit a vertical homogenity so that the delineation of the different sediment types must be done on lithologic aspect rather than by the law of superposition.

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CHAPTER I

INTRODUCTION

In the past decade knowledge of Late Quaternary carbonate sediments has been greatly extended by studies located on the Bahamian Platforms (Purdy, 1960), in the Gulf of Batabano (Daetwyler and Kidwell, 1959) and in Florida Bay (Ginsburg, 1956). These studies have all been sited on shallow carbonate shelves and have dealt with the origin and sediment/environment relationships of deposits formed during the closing stages of the post-glacial marine transgression. In contrast, the Late Quaternary carbonate sediments described in the present study have been obtained from the deeply-submerged, outer margins of the Yucatan Shelf (Campeche Bank). These sediments have been formed under prolonged conditions of marine transgression and as a result, questions of modern sediment/environment relationships here become subordinate to the problems of delineation of relict sediments, effect of environmental shift with rising sea level and the effect of admixing of relict and modern sediments on the total lithological aspect of the deposits.

Unconsolidated post-glacial (Holocene and Recent) sediments on the outer margin of the Yucatan Shelf (fig. 1) which are described in this paper, may be grouped into one areally and stratigraphically circumscribed unit termed herein, the Sigsbee blanket. This unit, which covers a broad area of the shelf and continental slope as a thin blanket, 3 inches to 4 feet thick, is composed dominantly of planktonic shells and tests with variable percentages of admixed ooids, calcareous pellets, lithic fragments and benthonic skeletons. Some of these constituents were deposited on the outer shelf under shallow-water transgressive conditions of Holocene time. Other constituents have been deposited under deep-water conditions similar to those existing on the shelf at present. Post-depositional admixing of shallow and deep-water constituents has resulted in a vertically homogeneous layer of sediment.

The objective of the present study was a reconstruction of the depositional history of the Sigsbee blanket by analysis of data concerning constituents, stratigraphic position and areal distribution of the facies types within the unit. This approach has allowed an evaluation of the effect of the post-glacial marine transgression, substrate lithology and post-depositional admixing of relict and modern constituents on the total character of the Sigsbee blanket.

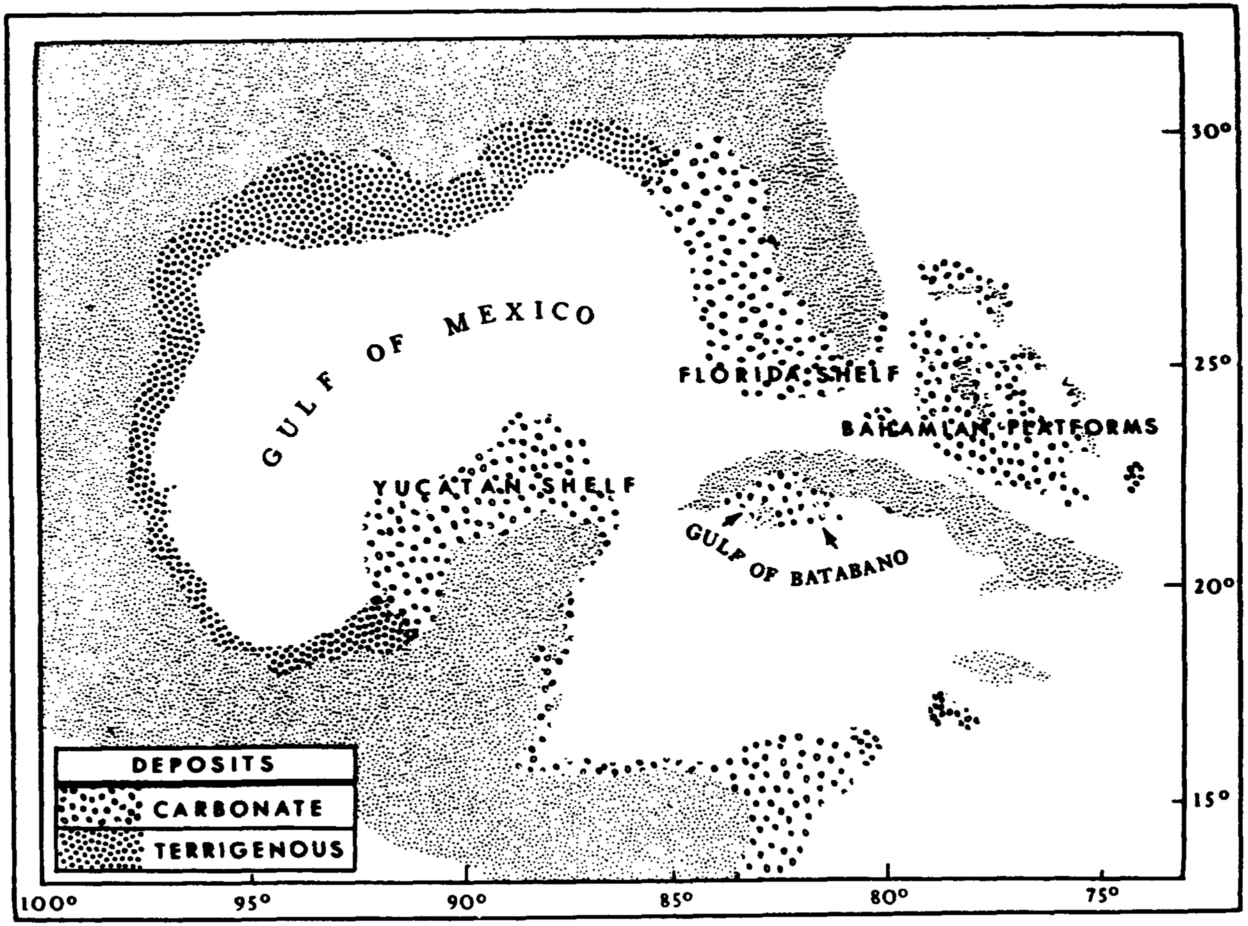

Figure 1. Location Map, Yucatan Shelf, Mexico.

CHAPTER II

LITERATURE REVIEW

No published studies of Late Quaternary sediments from deeply submerged carbonate provinces such as the outer margin of the Yucatan Shelf are available in the literature. Most of the studies of shelf sediments taken in depths comparable to the occurrence of the Sigsbee blanket (180 to at least 1200 feet) have been located on shelves where sediments have been introduced by riyers and the sediments are accordingly composed of terrigenous sand, silt and clay. Despite the obvious differences in sediment type brought about by provenance, several of the studies of deep terrigenous shelves have proved useful in interpreting the depositional history of the Sigsbee blanket in that they too, deal with factors affecting all modern continental shelves; these are the sea level oscillations of the Quaternary Epoch and in particular the major marine transgression of post-glacial (Holocene and Recent) time.

THE HOLOCENE TRANSGRESSION

The Sigsbee blanket is part of a sequence of sediments laid down under conditions of marine transgression during post-glacial time. This transgression, termed the Flanderian transgression by Dubois (1924) and the Holocene transgression by Curray (1960), has affected the shelves of the world. The underlying causes appear to be glacio-eustatic since there are suggestive correlations between the sequence of marine events and the sequence of events in connection with the continental ice sheet during the Wisconsin and Holocene (Curray, 1960 and Fairbridge, 1961). There is fair agreement on the general course of sea level rise between a low at -300 feet during the Wisconsin and the arrival of the shoreline at the vicinity of the present level (McFarlan, 1961; Curray, 1961; Shepard, 1960). Fisk and McFarlan (1955) and McFarlan (1961) propose the following sequence: a low stand at -450 feet at a Wisconsin stage older than 35,000 years B.P.; a stillstand at -250 feet or fluctuation of several thousand years duration between the -250 to -300 foot level (less than 35,000 to approximately 16,000 years B.P.) followed by a relatively continuous rise to the present level at approximately 4,000 years B.P. Curray (1960) suggests a glacial low in excess of -390 feet at approximately 18,000 years B.P., followed by a rise to present level with interspersed small reversals and/or hesitations in the transgression between -170 feet and -210 feet and between -60 feet and -120 feet. Curray (1960) goes further and correlates these events on the basis of radiocarbon chronology with local retreats and advances of the continental ice sheet of North America (Horberg, 1955).

Shepard (1960) takes a conservative approach and suggests a sea level rise from the -300 foot level to the present shoreline occurring between 17,000 years B.P. and 5,000 to 7,000 years B.P.

On the basis of data from the Yucatan Shelf, Logan (1963) suggests an interpreted sequence of events as follows. A prolonged stillstand at -300 feet during Wisconsin time; a rapid regression to a level in the vicinity of -450 feet at about 18,000 years B.P.; transgression to the present sea level during the period 18,000 years B.P. to present with possible small hesitations between the -170 to -210 foot level and the -100 to 120 foot level.

The interval of time marked by marine transgression between the -300 foot level and the present strandline is designated as Holocene as distinct from Recent which is the time interval in which the shoreline has been adjacent to its present level, probably from 5,000 years B.P.

THE HOLOCENE SEDIMENTARY SEQUENCE

Trowbridge (1954), Stetson (1953) and Curray (1960) note the wide occurrence of coarse quartz sands on the outer margin of terrigenous shelves and conclude that these sands are relict (not being deposited today) and are products of the lower sea levels that occurred in the early stages of the Holocene transgression. This conclusion was based on the fact that there is no feasible way to transport the sand-size particles to the outer margin of a deep wide shelf in the present physical regime, and on the evidence provided by relict faunas and radiocarbon dates.

Curray (1960) proposed a stratigraphic approach to the delineation of sediment types on the outer Texas Shelf. The surface sediments on the Texas Shelf are the product of the Holocene transgression and they are resting on an unconformity which is developed on the Pleistocene, Prairie formation or the Beaumont clay. These Pleistocene sediments are termed the "substratum" by Curray (1960). The unconformity is overlain by a sandy marine shoreline or near-shore, shallow-water deposit termed the "basal sands" and these in turn are overlain by Curray's "shelf facies" which is defined as the suspended sediments deposited seaward of the contemporary basal sands. The next sediments in this transgressive sequence are those of the "upper slope facies" which Curray (1960) states may be characterized by a high-proportion of planktonic tests and shells. The total sequence of basal sand facies, shelf facies and upper slope facies are grouped by Curray under the general term "Holocene series."

Several analogies can be drawn between this sequence of terrigenous sediments and the outer shelf deposits (Sigsbee blanket)

studied in this paper. The surface of erosion (unconformity) on the Yucatan Shelf is developed on the Campeche calcilutite (Wisconsin in age) between -450 and -300 feet and on calcite-cemented limestones of Wisconsin or pre-Wisconsin age above the 300 foot isobath. The carbonate analogues of the basal quartz sands of Curray (1960) are the calcareous pellets, ooids, lithic fragments and benthonic skeletal fragments in the Sigsbee blanket. The "shelf facies" of Curray (1960) is replaced by the skeletons of benthonic organisms and calcareous pellets which lived or, in the case of pellets, formed in the environment just seaward of the shallow-water, high energy marine shoreline. The "upper slope facies" on the Texas Shelf is quite similar to the planktonic lutite facies of the Sigsbee blanket in that both contain a high proportion of planktonic tests and shells and are situated on the outer shelf extremity and the continental slope.

PLANKTONIC ONLAP

The planktonic component of the sediments of the Sigsbee blanket is dominantly foraminiferal. According to Phleger (1960), planktonic foraminifera seem to be adjusted to the open ocean environment. Bandy (1956) and Phleger (1960) both state that the overall planktonic foraminiferal populations decrease as the shoreline is approached from deeper water whenever there is a distinct difference between the shelf water and oceanic water. In areas such as the Yucatan Shelf where the shelf water is essentially the same as oceanic water the composition of the planktonic foraminiferal fauna is essentially the same as that of the open ocean, Phleger (1960).

Curray (1960) reports that a planktonic onlap is observed in the sediments of the Texas Shelf and attributes this type of distribution to the difference in the shelf water and oceanic water and to the dilution of the planktonic content by the influx of terrigenous sediments near the shore. In other words, as the source of terrigenous sediments is neared, the increase in terrigenous debris tends to dilute the significance of the planktonic component.

ADMIXING OF SHALLOW-WATER AND DEEP-WATER FACIES AND ASSOCIATED MINOR SEDIMENTARY STRUCTURES

Trowbridge (1954) states that the sediments on the outer shelf margins of the northern Gulf of Mexico are the product of several different environments that have existed in this area during the Holocene transgression. Curray (1960) confirms this interpretation and further states that the onlap of the transgressive sequence has been confused by admixing of relict and later sediments due to animal

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burrowing and occasional stirring by hurricane wave currents. Animal burrows appear in cores from the outer shelf margin sediments on the Texas Shelf (Curray, 1960) and they are also present in cores taken from the Sigsbee blanket (Yucatan Shelf).

Bretschneider (1954) and Logan (1963) illustrate the effect of hurricane waves on shelf sediments at various depths in the Gulf of Mexico. It has been suggested that these periodic conditions cause lowering of wave base and consequent stirring of the sediments on the outer shelf.

The end product of the mixing processes is a thoroughly admixed sediment which exhibits a mottled to homogenous texture. It is probable that admixing is most effective in lithotopes where depositional rate is low or where the post-glacial transgression has caused a progressive decline in detrital influx.

SHALLOW-WATER CARBONATE SEDIMENTS

Studies of shallow-water carbonate constituents and facies in the Sigsbee blanket have been facilitated by the background of information available in the works of Vaughan (1914, 1924), Thorp, (1936), Illing (1954), Newell et al (1957) and Purdy (1960) on shallow-water carbonate sediments from the Bahamian Bank and of Ginsburg (1956) on the shallow-water carbonate sediments of Florida Bay. These studies have dealt with sediment/environment relationships and with the fundamental questions concerning the origin and environment of formation of sedimentary particles such as ooids, calcareous pellets, grapestone and lithoclasts.

CHAPTER III

METHODS OF STUDY

FIELD

The samples used in the present study were collected on cruises 62-H-2 and 62-H-9 of the R. V. HIDALGO, research vessel of the Department of Oceanography and Meteorology, Agricultural and Mechanical College of Texas. Samples were taken by means of 1) Van Veen surface grab sampler and 2) a gravity coring device having a 2 inch diameter core barrel. Location of sample stations was achieved by Loran, celestial navigation, land fixes and dead reckoning. Continuous bathymetric records were obtained by means of a Precision Depth Recorder (P.D.R.) and a Raytheon fathometer.

LABORATORY

Approximately 160 surface samples and 90 cores have been collected from the Sigsbee blanket (fig. 4). The surface samples and cores were described under a binocular microscope and grain size analysis was carried out on each surface sample. The sand fraction was separated and impregnated with plastic and thin-sectioned. About 100 thin sections were quantitatively analyzed by standard procedure, outlined by Ginsburg (1956), using a Zeiss G.F.L. polarizing microscope and a Swift electrical point counting stage and tabulator. After the results of the 100 point counts had been tabulated, 30 to 40 more thin sections were examined and visual estimates of constituent percentages were made. The silt and clay fractions of 25 samples were mounted on glass slides and examined under the high power lens of the polarizing microscope to determine their composition.[1] Radio-carbon dates were obtained on one ooid sample, one pellet sample and two plankton samples from the Sigsbee blanket. Distribution maps, based on the petrographic work, grain size curves, graphs and tertiary diagrams of relative sand, silt and clay percentages were made to help the writer interpret the data. The distribution maps and photomicrographs are used in the paper to illustrate the results of this analysis. The results of the point count tabulation and the grain size analysis are presented in Appendices I, II and III.

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[1] Planktonic skeletal constituents are recognizable in the silt-size fraction of carbonate sediments (Feray *et al.*, 1962).

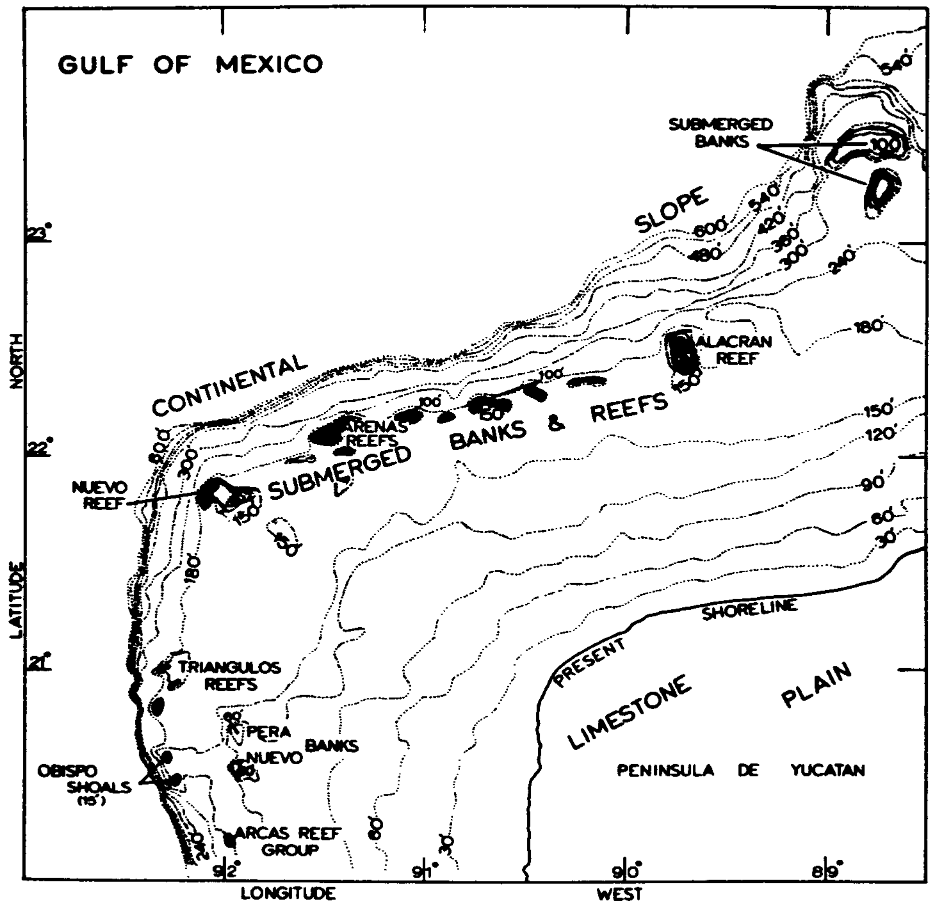


Figure 2. General Bathymetry.

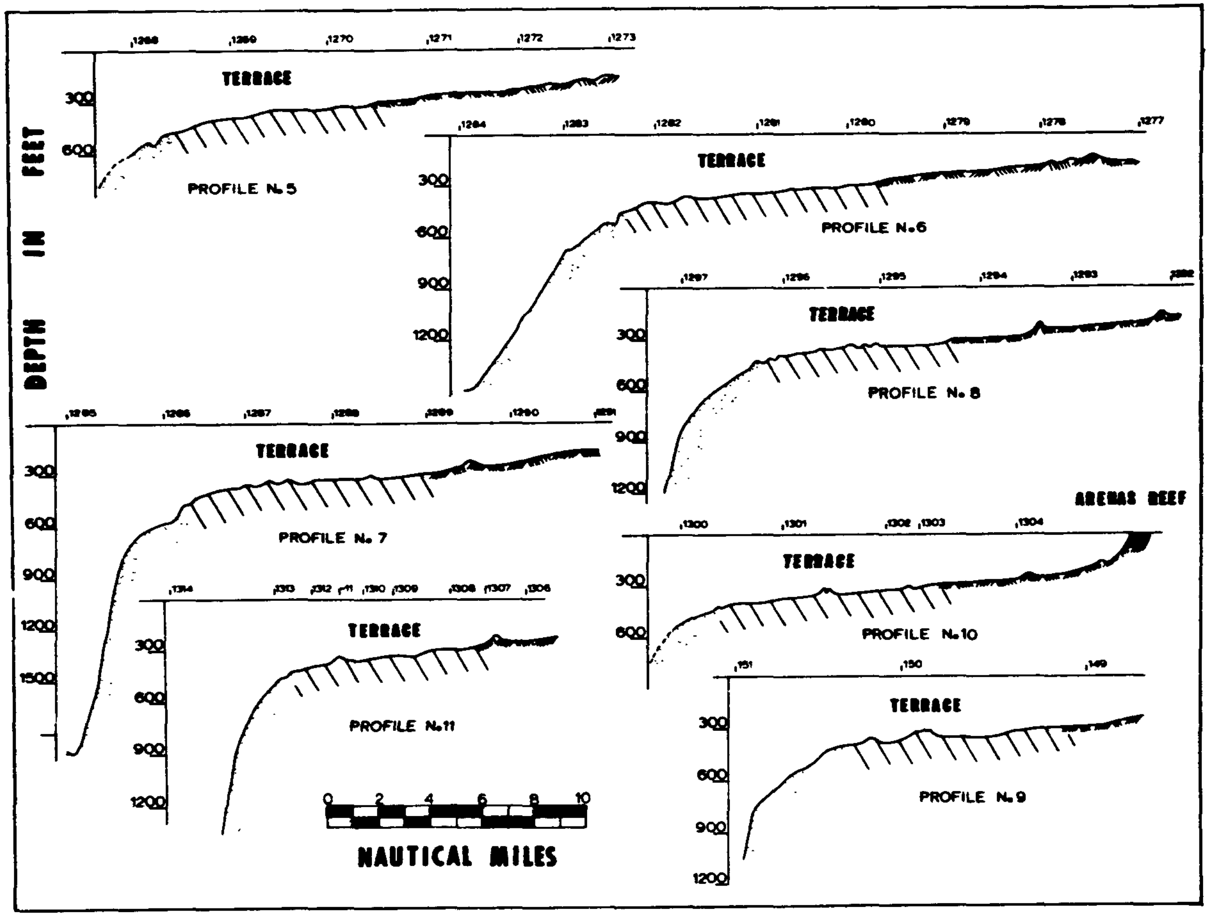


Figure 3. Bathymetric Profiles: small hashes = upper outer shelf; large hashes = outer shelf terrace; dots = outer shelf margin and continental slope. Station number at top of profiles coincide with station numbers on fig. 4.

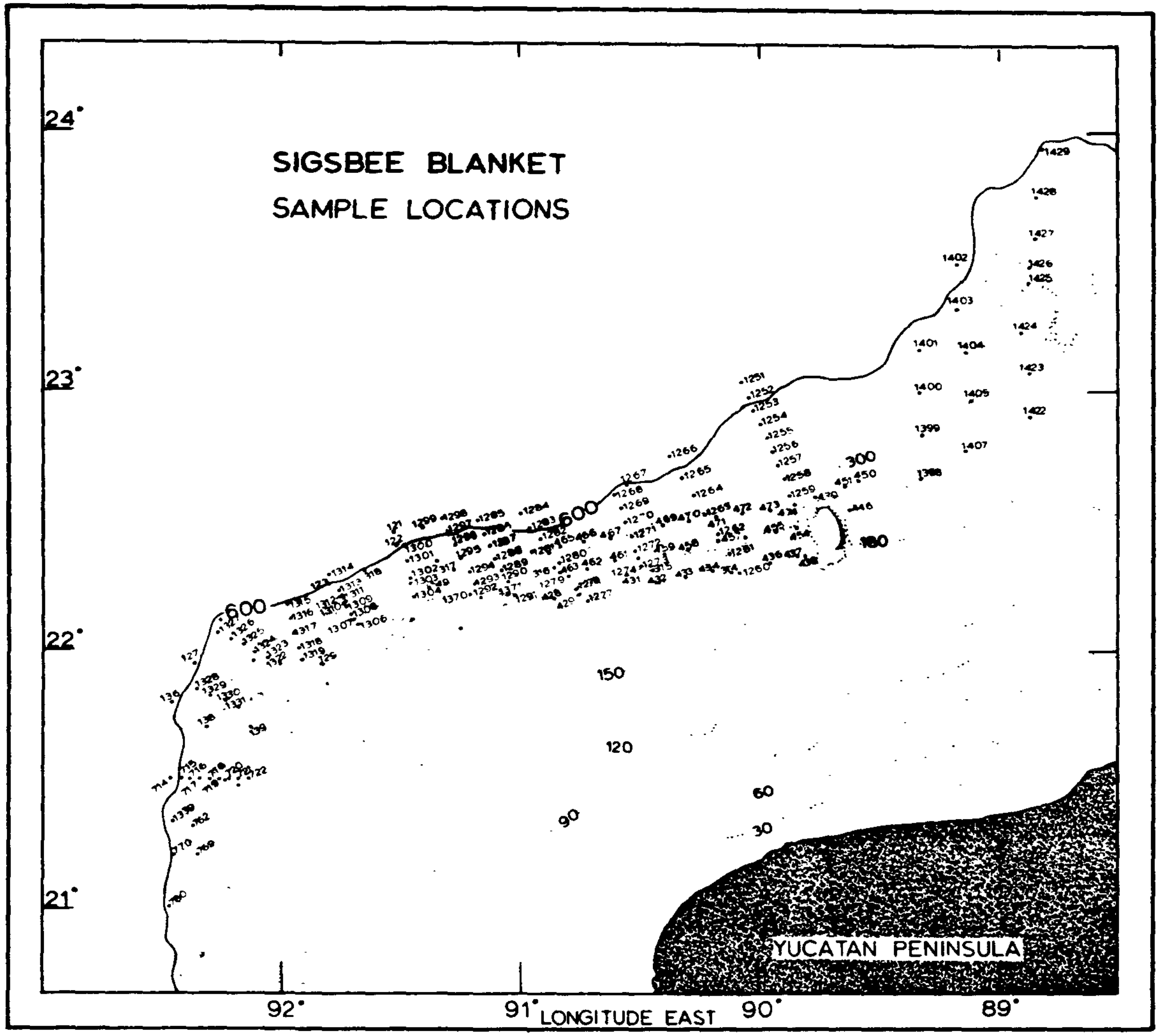


Figure 4. Station Location Map.

CHAPTER IV

LOCATION AND SETTING

The Yucatan Shelf (fig. 1) is the seaward extension of the Yucatan Platform, a tectonically stable block extending northward into the Gulf of Mexico from the east-west trending orogenic belt of Central America. The Yucatan Platform is capped by limestones of Tertiary and Pleistocene age (Logan, 1962). Most of what is today called the Yucatan Shelf was exposed during the lower sea levels of Wisconsin and early Holocene time. Since Wisconsin time, the Yucatan Shelf has undergone a rapid marine transgression which is reflected in bathymetric features on the shelf and in the type and distribution of Holocene sediments (Logan, 1963).

BATHYMETRY

The Yucatan Shelf can be sub-divided into two physiographic provinces: 1) inner shelf (0 to -180 feet), and 2) outer shelf (-180 feet to the shelf-edge break), on the basis of a well-defined change in slope at the 180 foot isobath.

The inner shelf averages about 60 miles in width (fig. 2) and has a gradient of about 3 feet/mile. The surface of the inner shelf is marked by numerous small irregularities. A chain of limestone (inorganic) banks, occasionally capped by reefs, forms a semi-continuous raised rim around the outer periphery (fig. 2).

The outer shelf varies in width from 30 miles to 5 miles, narrowing to the south along the western shelf margin toward 21° north latitude (fig. 2) and has a general gradient of about 6 feet/mile between the 180 foot isobath and the 450 foot isobath (fig. 3). The shelf gradient then becomes 25 feet/mile or more to the shelf-slope break (fig. 3). Terraces mark the outer shelf province of the Yucatan Shelf between the -180 to -210 feet levels and between the -450 feet to -300 feet. The outer shelf is divided into 3 bathymetric sub-divisions:

1) upper-outer shelf: This subdivision is bounded by the 180 foot and 300 foot isobaths and has a constant gradient of 6 feet/mile broken by a few ridges which may be aeolian dunes constructed during the lower sea levels.
2) outer shelf terrace: This feature lies between the 300 foot and 450 foot isobaths and has a gradient of 6 feet/mile and is bounded by a small escarpment at -300 feet (fig. 3, profiles 5, 6 and 8) and an abrupt change in slope at -450 feet (fig. 3).

3) outer shelf margin: This area is bounded by the 450 foot isobath and the shelf-edge break (about -660 feet). The gradient is about 25 feet/mile and the surface is rather flat with minor irregularities.

Near 21° north latitude, the outer shelf narrows to about 5 miles and the sub-divisions are not readily discernable on bathymetric profiles although the -300 to -450 foot level is usually marked by notching and a slight bathymetric break.

SEDIMENTS

The Yucatan Peninsula has no major rivers bringing terrigenous sediments to the Yucatan Shelf due to the karst drainage system developed in the Tertiary and Pleistocene limestones which surface the region (Krutak, 1962 and West, 1962). The effect of the karst topography on drainage is reflected in the dominant carbonate sedimentary suite lying on the shelf floor (Logan, 1963). Carbonate sediments of the Yucatan Shelf are composed of skeletal and non-skeletal grain types. The skeletal fraction is composed of molluscan, coral, foraminiferal, echinoidal and calcareous algal fragments while the non-skeletal fraction is dominated by calcareous pellets, ooids, and lithic fragments. Ooids and pellets are restricted to the outer shelf area while the inner-shelf sediments are mainly skeletal and lithic fragment sands (Logan, 1963).

The sediments of the Yucatan Shelf can be divided into lithological units on the basis of gross sediment type (Logan, 1962). The Sigsbee blanket which is one of these lithologically distinct units occurs on the outer shelf and continental slope.

PRESENT PHYSICAL ENVIRONMENT

The Sigsbee blanket is restricted to the outer shelf and continental slope provinces of the Yucatan Platform in water ranging from -180 to at least -1200 feet in depth. Over this depth range the salinity varies from 35 parts per thousand to 36 parts per thousand and the temperature ranges from 24° Centigrade to 9° Centigrade (Nowlin and McLellan, 1963). Since the Sigsbee blanket is restricted to the deeply-submerged portion of the Yucatan Shelf, it is below normal wave base and only hurricane waves can cause any stirring of the sediments (Logan, 1963).

STRATIGRAPHIC SETTING

The Sigsbee blanket is composed dominantly of a planktonic lutite which contains varying amounts of calcareous pellets, ooids, lithic fragments and benthonic skeletal fragments. The unit ranges from 3 inches to 4 feet in thickness and exhibits a homogenous to mottled texture similar to that described by Curray (1960) in his description of the outer shelf margin sediments on the Texas shelf. The unit covers the outer shelf from the northernmost point on the shelf to 21° north latitude and in a few instances it occurs as tongue-like extensions between the marginal (inorganic banks) hills on the inner shelf (figs. 2 and 9). The contact between the Sigsbee blanket and the benthonic skeletal calcarenites of the inner shelf province is a lateral gradation discussed later in this paper. The seaward extent of the Sigsbee blanket is undetermined, but the unit is thought to extend to the floor of the Sigsbee Deep. The upper boundary of the unit is the sediment water interface. The lower boundary of the Sigsbee blanket is variable and ranges from an unconformable contact on the upper-outer shelf to a conformable contact on the outer shelf margin and continental slope.

The Sigsbee blanket unconformably overlies calcite-cemented limestones on the upper-outer shelf sub-division (180 to 300 feet depth). This conclusion is based on the following petrographic and field evidence: Calcite-cemented lithic fragments occur in the Sigsbee blanket samples from the upper-outer shelf (Plate III, figs. 1 and 2). These lithic fragments are the products of the erosion of the underlying substrate in this area. Core recovery in this area consists of the unconsolidated Sigsbee blanket sediments and the dented nose cones of the coring device indicate hard rock immediately below the unconsolidated layer.

The contact between the Sigsbee blanket and the underlying Campeche calcilutite on the outer shelf terrace (-300 to -450 feet) is also interpreted as an unconformity (Logan, 1963). The evidence for this conclusion is as follows 1) lithic fragments present in the Sigsbee blanket, in this area, resemble the gross lithology of the underlying Campeche calcilutite and are lithologically distinct from the lithic fragments that occur on the upper-outer shelf (Harding, 1963), 2) a sharp mineralogy change between the fine fraction of the Campeche calcilutite (aragonitic) and the overlying Sigsbee blanket (calcitic) in this area and 3) irregular bottom topography suggests that the area between the 300 foot and 450 foot isobaths is in part, erosional (Logan, 1963). Below the 450 foot isobath the contact grades from a submarine disconformity (wave base erosion) to a conformable contact somewhere near the shelf-slope break (Logan, 1963)

CHAPTER V

TEXTURAL/COMPOSITIONAL GROUPS

The Sigsbee blanket occurs on the outer shelf and continental slope provinces of the Yucatan Shelf. On the basis of sand-silt-clay percentages and composition, the sediments may be placed into four major groups (figs. 6, 7 and 8).

TEXTURAL/COMPOSITIONAL GROUP 1

The sediments which fall into textural/compositional group 1 are white to yellow-brown, moderately to poorly-sorted (average graphic sorting coefficient of 1.07 phi units) medium to coarse-grained calcarenites (fig. 6). The typical lithology is a calcarenite (fig. 6) composed dominantly of non-skeletal grains (ooids, pellets, lithic fragments) that range between 55% to 85% of the total sediment and of benthonic skeletal fragments of mollusks, echinoids, foraminifera and coralline algae ranging from 15% to 45% (fig. 7).

TEXTURAL/COMPOSITIONAL GROUP 2

The sediments in textural/compositional group 2 are gray, medium to coarse-grained, moderately to poorly-sorted (average graphic sorting coefficient of 1.8 phi units) calcarenites with a silt content ranging from 15% to 45% (fig. 6). The typical *in situ* sediment from cores is a homogenous to mottled (burrowed) ooid-pellet calcarenite with a silt matrix composed of fragments and whole tests and shells of planktonic foraminifera, pteropods and gastropods. The planktonic component also accounts for 10% to 30% of the particles in the sand fraction (fig. 7).

In group 2, a crude straight line relationship exists between the percentages of planktonic tests and shells in the sand fraction and the silt fraction percentage of the total sample. The contribution of silt-size planktonic material varies independently from the non-skeletal/benthonic skeletal grain ratio in group 2 samples. The independence between the planktonic component of the samples and this ratio is statistical support for the observation that the planktonic fraction is not genetically related to the non-skeletal and benthonic skeletal calcarenite fraction. The planktonic content varies according to station depth with a general decrease in planktonic and planktonic silt content with decreasing depth (fig. 5).

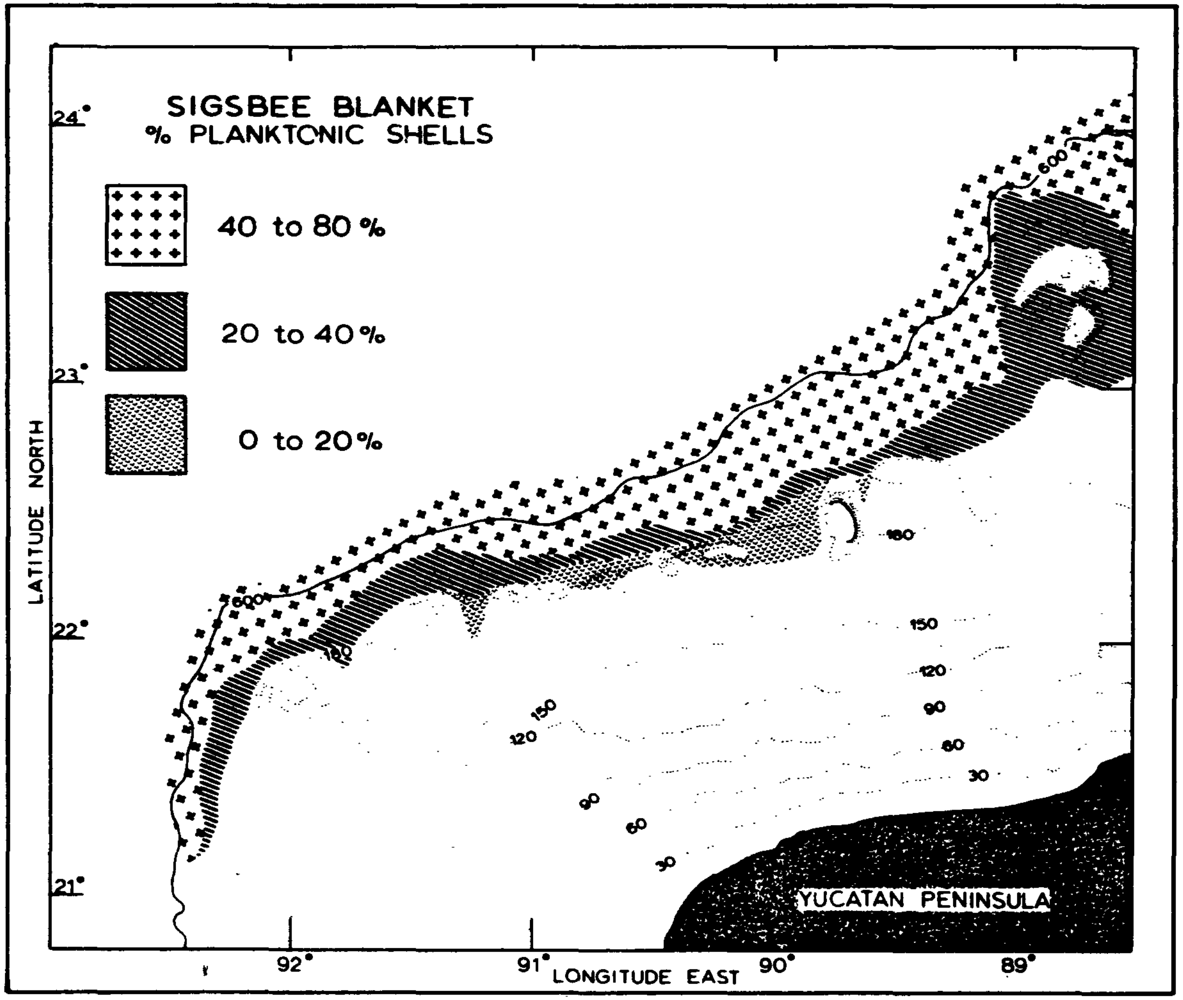


Figure 5. Distribution of Planktonic Tests and Shells.

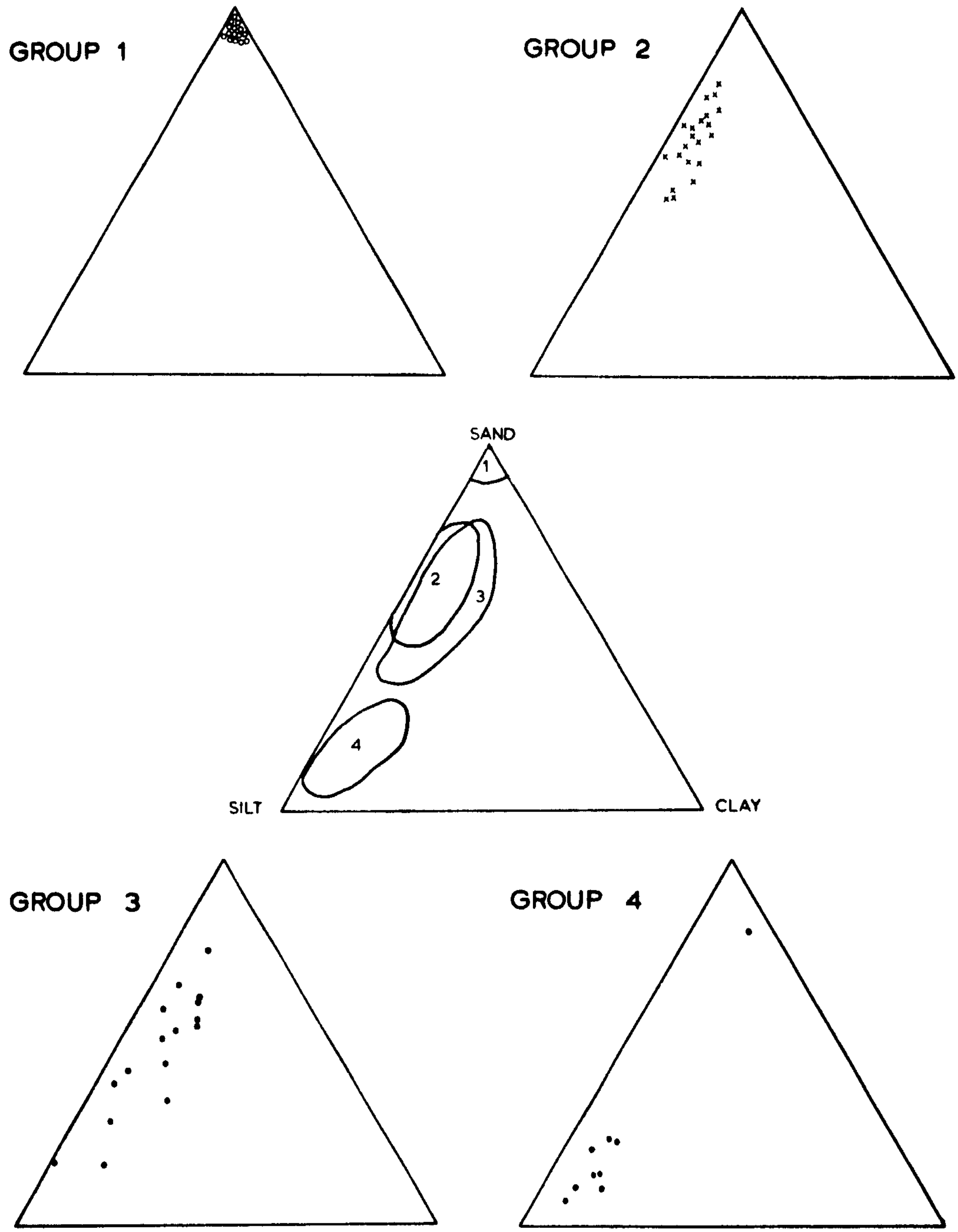


Figure 6. Relative Sand-Silt-Clay Percentages of Textural/ Compositional Groups. Center diagram illustrates general fields of all groups.

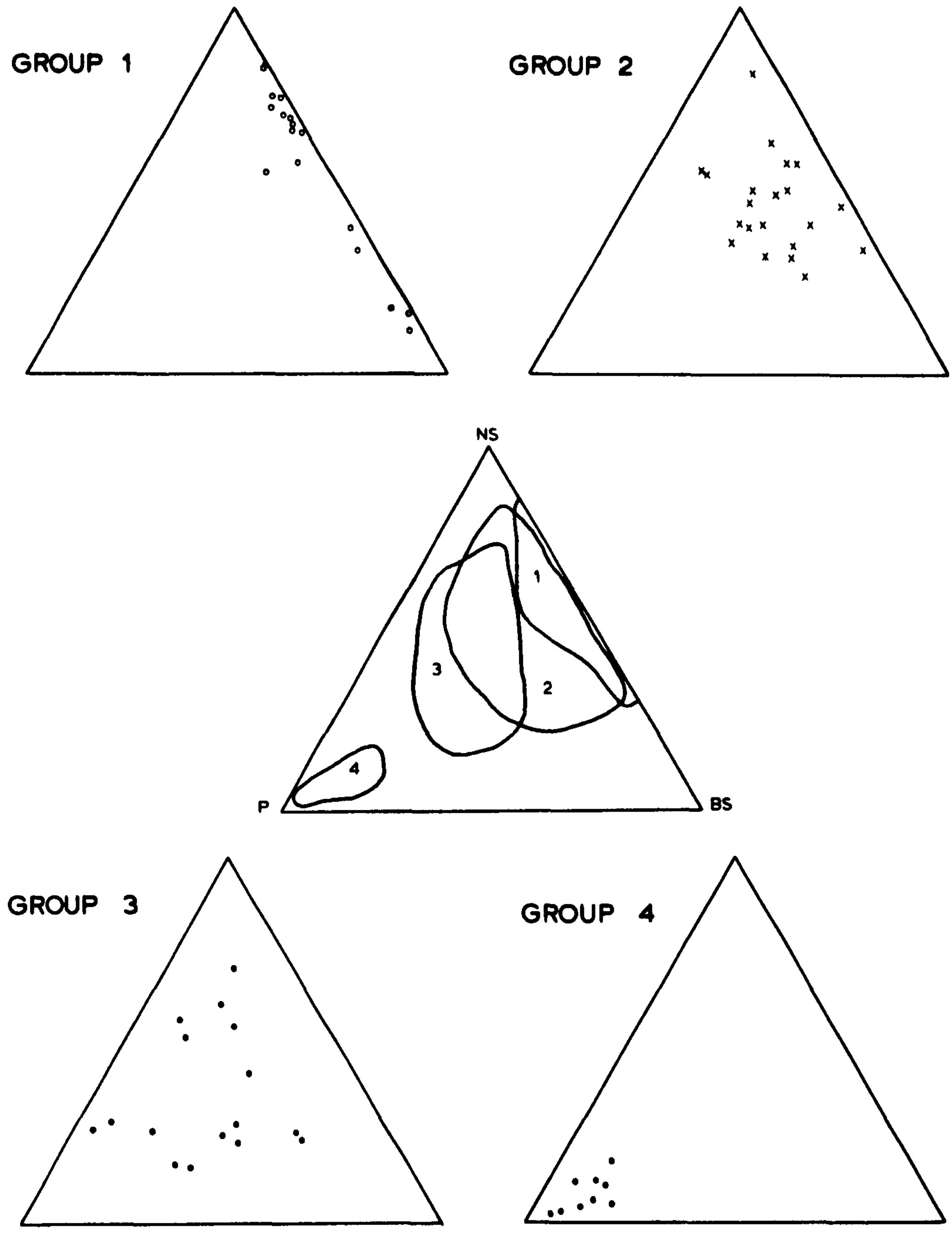
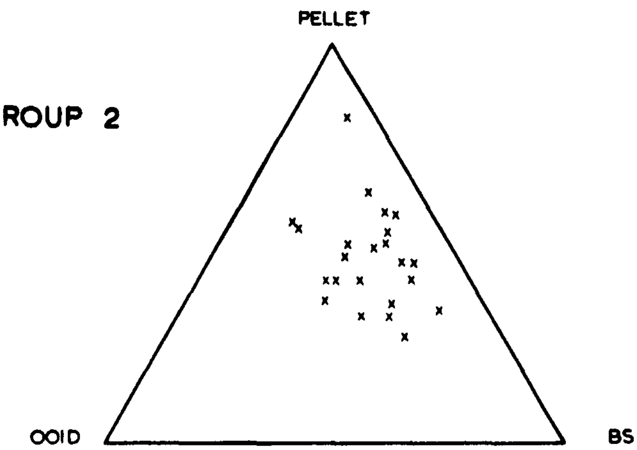


Figure 7. Non-Skeletal, Benthonic-Skeletal, Planktonic Percentages of Textural/Compositional Groups. Center diagram shows general fields of all groups.

GROUP 2



GROUP 3

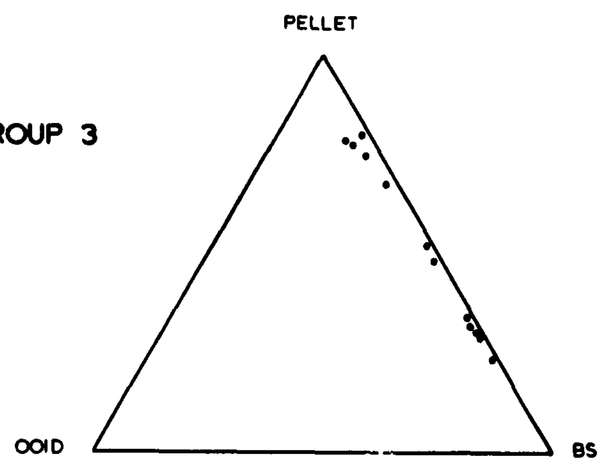


Figure 8. Comparative ooid, pellet and benthonic skeletal grain percentages in textural/compositional groups 2 and 3.

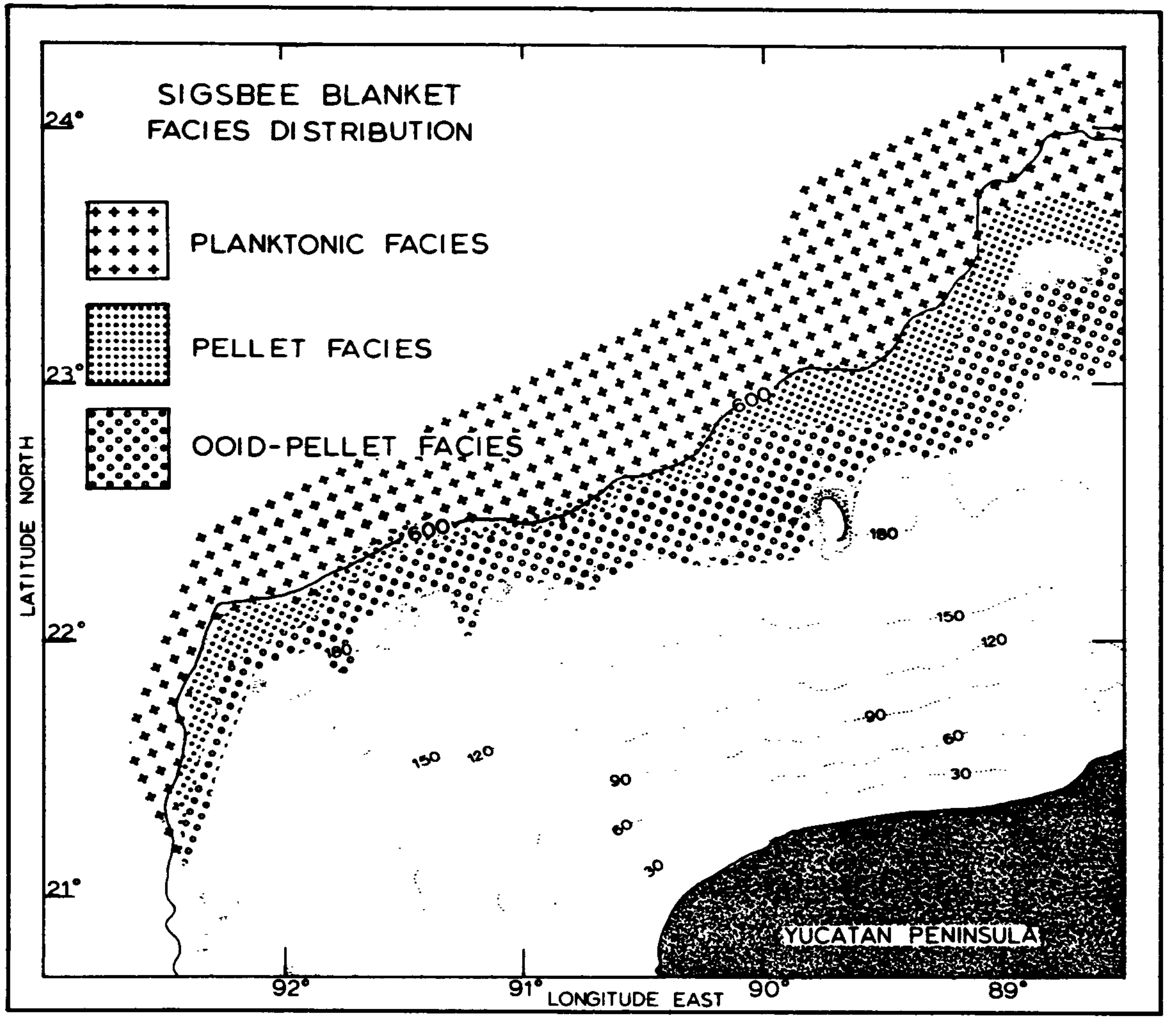


Figure 9. **Facies Distribution: both ooid-pellet calcarenite facies shown as ooid-pellet facies, pelletal calcarenite facies as pellet facies, planktonic calcilutite as planktonic facies.**

Skeletons and skeletal fragments of benthonic mollusca, foraminifera, anthozoa, coralline algae, echinoids and bryozoa form from 15% to 50% of the sand fraction while the non-skeletal constituents (ooids, pellets lithic fragments) range from 35% to 65% (fig. 7). The non-skeletal/benthonic skeletal grain ratio in samples falling into group 2 is similar to the non-skeletal/benthonic skeletal grain ratio of group 1. The similarity of these ratios along with the independent variability of the planktonic and silt content in group 2 suggests that these sediments are polygenetic admixtures; that is, products of the admixing of the group 1 sands with later planktonic debris of sand and silt-size. The planktonic sediments are similar in properties to sediments forming textural/compositional group 4 which occurs in the planktonic calcilutite facies of the Sigsbee blanket. In other words, if the planktonic contribution to the sediments of group 2 is removed by calculation, the sediments revert to relatively clean calcarenites that are lithologically identical with the sediments which form group 1.

TEXTURAL/COMPOSITIONAL
GROUP 3

The sediments which fall into textural/compositional group 3 are medium to fine-grained, moderately to poorly-sorted (average graphic sorting coefficent of 1.5 phi units) calcarenites with a silt fraction ranging from 15% to 55% at the extremities and with most of the sediments falling into the 25% to 45% silt content range (fig. 6). The sand content varies between 40% and 75% in the group 3 sediments (fig. 6). The typical lithology of the group 3 sediments is a non-skeletal portion (dominantly calcareous pellets) ranging from 15% to 70%, a benthonic skeletal portion composing from 10% to 40% of the sand fraction and a planktonic component that accounts for the major portion of the silt fraction and also composes 25% to 55% of the sand fraction (fig. 7).

As in group 2, a crude straight line relationship exists between the planktonic component of the sand fraction and the relative percentage of silt-size particles. The planktonic component is independent of the non-skeletal/benthonic skeletal ratio in group 3 sediments which is also similar to the group 2 sediments and has the same polygenetic connotations. The major difference between the group 2 sediments and the group 3 sediments lies in the non-skeletal fraction where the group 3 sediments are dominated by calcareous pellets (20% to 80%) and lack appreciable ooids and lithic fragments.

TEXTURAL/COMPOSITIONAL
GROUP 4

The sediments of textural/compositional group 4 are gray, moderately-sorted (average graphic sorting coefficient of 0.6 phi units) planktonic calcilutites with a silt fraction ranging from 65% to 85% of the total sample (fig. 6) and a sand fraction that composes from 10% to 25% of the total sample. Only one sample in this group falls outside the above range, sample 1251, which is 80% sand-size particles, however its composition (90% planktonic tests and shells, fig. 7) places it in the group 4 class. The typical in situ sediment from cores is a homogenous calcilutite composed of from 70% to 95% planktonic test and shells (fig. 7).

CHAPTER VI

CONSTITUENTS

Sediments of the Sigsbee blanket contain eight major constituent grain types, these are: 1) whole shells and tests of planktonic foraminifera, pteropods and gastropods, 2) calcareous pellets, 3) ooids, 4) non-skeletal aggregate grains, 5) lithic fragments or lithoclasts, 6) fragments of calcareous algae, 7) whole and broken tests of benthonic foraminifera and 8) fragments of mollusca, echinoids, coral and bryozoa. Analysis shows that the Sigsbee blanket is dominated by a lithology of planktonic calcilutite with admixed non-skeletal and benthonic skeletal grains. The most evident variation within the unit is in relative percentages of ooids, pellets and planktonic tests and shells.

PLANKTONIC TESTS AND SHELLS

The planktonic tests and shells that occur in the Sigsbee blanket are dominantly foraminiferal (Plate III, fig. 3) with occasional pteropod and planktonic gastropod shells. Globigerina, Globorotalia and Orbulina are the most common planktonic foraminiferal genera in the sediments of the Sigsbee blanket. Planktonic foraminiferal tests and shells range from 1.00 mm to less than 0.06 mm in diameter. Chamber arrangement, shape and the typical foraminiferal wall perforations are diagnostic properties of the planktonic component of the sediments examined in this study.

From the examination of the silt fraction of 25 samples from the Sigsbee blanket the planktonic tests and shells were found to form the dominant portion of the silt fraction of the sediments and are also present in the sand fraction in percentages ranging from 10% to 95% where they occur as fragments and as whole tests and shells. The planktonic sediments occur in a continuous onlap from the continental slope to the vicinity of the 240 foot isobath and there is a general decrease in percentage of planktonic constituents with decreasing depth shoreward (fig. 5).

The planktonic tests and shells in the Sigsbee blanket are the skeletons or organisms which usually live in the upper 300 meters of the ocean. On the death of the organisms, the tests or shells settle to the bottom. Phleger (1960) reports the recovery of empty planktonic tests in shallow plankton tows which indicates that the sinking of the tests does not occur immediately after death.

ORIGIN OF PLANKTONIC TESTS AND SHELLS IN THE SIGSBEE BLANKET

Extensive deposits of planktonic tests and shells are characteristic of deep oceanic environments and have been reported on the floor of the Sigsbee Deep (Ewing et al., 1958) and on the continental slope provinces of the Yucatan Platform (Creager, 1958). Curray (1960) also reports an extensive deposit of planktonic tests and shells (mainly foraminiferal tests) on the outer shelf margin and continental slope provinces of the Texas Shelf. The onlapping distribution of planktonic sediments onto the continental shelves can be attributed to the encroachment of a deep-water depositional environment onto the shelf margins.

CALCAREOUS PELLETS

The calcareous pellets occurring in the sediments of the Sigsbee blanket can be divided into three types on the basis of petrographic properties: 1) micritic pellets, 2) arenaceous pellets and 3) crustacean faecal pellets.

Micritic Pellets (Plate 1, fig. 1)

The term micritic pellet is applied to ellipsoidal, ovoid or rod-shaped grains composed of structureless cryptocrystalline aragonite (mud or "micrite"). In general, the pellets have a homogenous fabric of randomly-oriented aragonite crystals; occasional minute inclusions may be recognized as shell fragments or spicules. The micritic pellets range up to 1 mm in length and 0.25 to 0.5 mm in cross-sectional diameter. In reflected light the grains are usually yellow-brown, white or greenish-black in color, the outer surface is smooth but is occasionally pitted with numerous small holes which are probably the work of boring organisms. In thin section, the micritic pellets are brown to greenish-brown in color and in some cases they contain randomly distributed dark, indeterminate inclusions which Illing (1954) and Purdy (1960) suggest may be refractory organic matter or an iron sulphide staining. Some of the pellets contain the green authigenic mineral glauconite which Moore (1939) notes as a common constituent of faecal pellets. Some of the micritic pellets have a narrow peripheral band of clear indeterminate material and a more cloudy, irregular interior. Purdy (1960) has observed this phenomena in calcareous pellets from the Bahamian Platforms.

Micritic pellets are a common constituent of the sand fraction in sediments of the Sigsbee blanket; the pellets commonly form nuclei for oolitic accretion and also occur abundantly as an allochem in the lithic fragments within the unit. The pellets are distributed continuously across the outer shelf in a depth range from 170 to about 600 feet.

Origin of Micritic Pellets

The term "micritic pellet" is used in the present study to distinguish this categroy from other pellets which possess intra-granular structures diagnostic of origin. Micritic pellets exhibit few characteristics on which to base genetic criteria. The majority of pellets in carbonate sediments and rocks are the micritic type. The term is a modification of "micrite" from Folk (1959) and refers to grains or sediments which were once mud-like. Micritic pellets are grains composed of mud-size carbonate particles smaller than 0.03 mm (Leighton and Pendexter, 1962). Micritic pellets can be formed by a variety of lithogenetic processes, they may be formed penecontemporaneously with the deposition of the primary calcareous mud or by later erosion of semi-lithified micrites.

Micritic pellets may be formed by intraformational reworking of aragonitic muds by burrowing and scavenging organisms such as worms, mollusks, crustaceans and fish. The fine particles are ingested, passed through the alimentary tract, agglutinated with organic mucus and extruded as soft faecal droppings (Moore, 1939). The soft calcareous pellets may then be hardened by intragranular precipitation and recrystallization of aragonite within the mesh of crystals (Illing, 1954 and Purdy, 1960).

Intraformational reworking by mechanical processes may also account for the formation of micritic pellets. In this case the pellets are formed by accretion, possibly aided by binding organic mucus and algal threads, when fine aragonite and other mud-size particles adhere to one another during periods of transport and deposition. The soft aggregate is hardened by progressive precipitation and recrystallization of the aragonite within the grain. The cementing process may be facilitated by the presence of included organic matter and by bacterial action. Micritic pellets formed by mechanical erosion and deposition of lime muds are a special type of intraclast (Folk, 1962). Erosion of cryptocrystalline limestones (micrites) on the sea floor may also produce rounded to ovoid grains with the properties of micritic pellets. Pellets produced in this manner are lithoclasts and represent periods of erosion and interformational deposition.

Moore (1939) reviewed the question of origin of calcareous and noncalcareous pellets in modern marine sediments and concluded that pellets similar to the micritic pellets (as defined in this paper) were faecal in origin. Thorp (1936) and Purdy (1960) concluded

that the structureless, ovoid to ellipsoidal pellets in Bahamian sediments were probably of faecal origin but suggested that other mechanisms could produce this grain type. Kornicker and Purdy (1960) describe a highly-pelletal lime mud in the quiet waters of the Bimini Lagoon, Bahamas, the soft and friable pellets were believed to be the faecal product of a small gastropod (Batillaria minima) inhabiting the area. Pellets similar to the micritic pellet have been produced in the laboratory by direct precipitation of aragonite from sea-water, these pellets were formed along with a large quantity of fine flocculent precipitate (Vaughan, 1924; Mongahan and Lytle, 1956).

The primary origin of the micritic pellets from the Sigsbee blanket cannot be ascertained from the available evidence; it is, however, certain that the pellets are not forming in the present environment. This will be discussed further on a later page.

Arenaceous Pellets (Plate II, fig 2)

Arenaceous pellets are ellipsoidal, ovoid to rod-shaped grains composed of fine sand-to silt-size carbonate particles set in a matrix of randomly-oriented cryptocrystalline aragonite. The pellets range up to 1 mm in length and 0.5 mm in cross-sectional diameter. In reflected light, these pellets are yellow-brown to greenish-black in color with a smooth surface interrupted by occasional pits formed by later boring organisms. The detrital grains which are incorporated in the arenaceous pellets may be superficial ooids, smaller micritic pellets and occasional skeletal fragments; the grains are usually concentrated toward the center of the pellet. In many of the arenaceous pellets, the central zone has a dark cloudy matrix which may be due to the inclusion of organic matter or staining by ferrous sulphide. The concentration of coarser grains at the center of the pellet is bounded by a peripheral coating of randomly-oriented cryptocrystalline aragonite. The arenaceous pellets which occur in the Sigsbee blanket are probably of faecal origin, since they strongly resemble, in their agglutinate texture, faecal pellets described by Moore (1939).

Crustacean Faecal Pellets (Plate II, figs. 1, 3 and 4)

Crustacean faecal pellets from the Sigsbee blanket are rod-shaped, dorso-ventrally flattened, grooved pellets composed of randomly-oriented cryptocrystalline aragonite similar in texture to the micritic pellet type. The pellets range up to 5 mm in length and 0.5 mm in cross-sectional diameter. In thin section, the pellets are greenish-brown to brown in color. The diagnostic feature of crustacean faecal pellets is the presence within the grain of a drainage canal system (Moore, 1932). In longitudinal section, the drainage canals appear as equally-spaced strips (0.03 to 0.06 mm in width) parallel to the long axis of the grain (Plate II, fig. 1); in cross-section the canals appear as crescentic or kidney-shaped holes arranged in a bilaterally symmetrical pattern

about the longitudinal axial plane of the grain (Plate II, fig. 4). The canals may be hollow or filled with foreign material. In some pellets the canals are filled with an opaque black substance of indeterminate nature; the canals are often lined with radiating needle-like crystals of ?aragonite which project towards the center of the canal. In a few crustacacean faecal pellets, smaller ooids, pellets and/or shell fragments have been included in the pellet (Plate II, fig. 3). Crustacean faecal pellets occurring in the allochem portion of lithoclasts (rock fragments) from the Sigsbee blanket exhibit the canal structure with infillings of sparry or blocky calcite (Plate III, fig 1) occasional individual pellets may also contain canal linings of blocky calcite and these grains can be plausibly interpreted as remanie pellets eroded from the pelsparites underlying the Sigsbee blanket.

Crustacean faecal pellets occur as individual grains, as the nuclei of ooids, and as allochems in some lithic fragments. With the exception of sample 1307 (which has 15% of the sand fraction composed of crustacean faecal pellets), the crustacean faecal pellets account for less than 7% of the sand fraction in samples from the Sigsbee blanket. Many of the pellets in sample 1307 have blocky calcite partially filling some of the drainage canals (Plate II, fig. 3) suggesting a local remanie origin. Moore (1932) describes various types of crustacean faecal pellet and links pellet structure to parent organisms. The identification of the different types of pellet is based on the varied arrangement of the drainage canals.

ORIGIN OF CALCAREOUS PELLETS IN THE SIGSBEE BLANKET

The calcareous pellets in the Sigsbee blanket occur in a continuous sequence from -600 to -170 feet. Since the pellets are composed of fine-grained aragonitic "mud" and the fine material available for pellet production in the presently defined Sigsbee blanket is dominantly calcitic (planktonic tests and shells), the pellets cannot be derived from the Sigsbee blanket by intraformational processes. The only source for the pellets, on the Yucatan Shelf today seems to be the underlying Campeche calcilutite, which contains both hard pellets and a fine matrix of aragonitic mud.

A radiocarbon date of 10,980 ± 300 years B.P. on pellets from the Sigsbee blanket does not indicate a genetic relationship between the Campeche calcilutite and the Sigsbee blanket pellets in that the Campeche calcilutite is Wisconsin in age (about 18,000 years B.P.). However, the introduction of younger carbon into the pellets within the Sigsbee blanket could account for the younger date. The correlation of pellet occurrence in the Sigsbee blanket, below the 300 foot isobath, and the areal distribution of the underlying Campeche calcilutite certainly indicates some sort of relationship between the two units.

The pellets in the Sigsbee blanket, if genetically related to the Campeche calcilutite, could have been displaced from the underlying unit by two methods; 1) burrowing, mud-ingesting organisms and 2) mechanical reworking. In the case of the burrowing, mud-ingesting organisms, the aragonitic mud would be taken in by the organism in the Campeche calcilutite. The organism could then burrow upward into the Sigsbee blanket and excrete the pellet of aragonite mud within the overlying unit. This process could have taken place any time during the post-glacial transgression and the introduction of younger carbon (cementation of the pellet) would bias the radiocarbon date. The second process would simply rework the pellets from the Campeche calcilutite by mechanical erosion or winnowing of the fine aragonite mud away from the larger pellets. The correlation of the presence of a surface of erosion on top of the Campeche calcilutite and the occurrence of pellets in the overlying Sigsbee blanket indicates that this may have been the dominant process of pellet deposition, as opposed to formation, in the Sigsbee blanket. Again the radiocarbon date would have to be explained by the introduction of younger carbon.

On the basis of the radiocarbon date, it is necessary to postulate a transgressive aragonitic mud environment that moved with the advancing shoreline across the outer shelf. According to the wide distribution of pellets in the Sigsbee blanket and the large areal occurrence of this unit, it does not seem feasible that such an environment could have existed throughout the present area of pellet occurrence. Above the 300 foot isobath, some of the pellets show evidence of having been worked out of the underlying sparitic limestone. There does not seem to be any one theory to explain the origin of the pellets in the Sigsbee blanket and the only way to explain the evidences obtained in this study is with multiple hypotheses. Due to the correlation between the occurrence of pellets in the Sigsbee blanket and the distribution of the Campeche calcilutite, below the 300 foot isobath, the writer is inclined to believe that the pellets in the Sigsbee blanket, below this level, are genetically related to the Campeche calcilutite. Pellets above the 300 foot isobath are erosional products (in part) of the underlying pelsparitic limestones. There is also a possibility of pellet formation as a result of a transgression by a mud facies that is no longer present in the area. The radiocarbon date of 10,980±300 years B.P. is the only evidence supporting the postulated transgressive mud environment of Holocene age.

OOIDS

There are five varieties of oolitically-coated grains (ooids) in the Sigsbee blanket, these are: 1) superficial ooids, 2) semi-mature ooids, 3) mature ooids, 4) two-stage ooids and 5) oolitically-coated grapestone aggregates. The categories of oolitically-coated grains are distinguished in thin section on the basis of intragranular texture and structure, the number of oolitic laminae and the constitution

of the nucleus. Basically the ooid is composed of a nucleus, which may by formed by any grain type (pellet, skeletal fragment or grapestone aggregate) and an outer envelope of concentric laminae of aragonite. The laminae of the envelope are usually composed of aragonite crystals in which the long axes of the crystals are arranged tangential to the surface of the grain. In some oolitic grains the laminae of tangentially-arranged aragonite are interlaminated with layers of radially-arranged aragonite crystals (Plate I, fig. 4). Superficial, semi-mature and mature ooids are distinguished on the basis of the number of concentric laminae in the envelope. The superficial ooid (Plate I, fig. 2) is characterized by 1 to 2 concentric bands in the envelope; ooids with 2 to 10 concentric bands are designated as semi-mature (Plate I, fig. 3); ooids in which there are more than 10 concentric bands in the envelope are termed mature (Plate I,, fig. 4). Two-stage ooids (Plate I, fig. 5) are grains in which there have been two stages of oolitic coating separated by fine-grained, randomly-oriented aragonite "mud" that has the same textural characteristics of the micritic pellets. In the oolitically-coated grapestone aggregates, a grapestone aggregate serves as the nucleus for the development of the oolitic envelope (Plate I, fig. 6). The lumpy nature of the normal grapestone aggregate leads to the formation of an irregular ooid characterized by re-entrants in which the envelope is often thicker than on the outer surface of the grains (Purdy, 1960).

Semi-mature and superficial ooids are the most abundant type of oolitically-coated grain in the Sigsbee blanket. Most of these grains are coated micritic pellets with a few concentric laminae around the periphery. The two-stage ooids, mature ooids and oolitically-coated grapestone aggregates are sparsely distributed in the Sigsbee blanket; they occur in only a few samples and never exceed more than 5% of the sand fraction. Ooids are continuously distributed throughout the Sigsbee blanket in a broad zonal band between the 170 foot and 450 foot isobaths, with occurrences in the tongue-like extensions of the Sigsbee blanket between the marginal inorganic banks. The ooids form 5% to 52% of the sand fraction in the sediments from the 170 to 450 foot depth zone; they are invariably associated with calcareous pellets, lithic fragments and skeletons of shallow-water benthos. In the depth zone between the 170 and 300 foot isobaths many of the ooids have a relict peripheral rim of blocky calcite crystals (Plate II, fig. 6), while in the area below the 300 foot isobath, occasional ooids have a peripheral border of micritic cement. The attached cements suggest that these ooids have eroded from the underlying Wisconsin and pre-Wisconsin sediments and rocks.

ORIGIN OF OOIDS

Ooids have been a controversial subject for many years. Some of the major contributions to the ooid problem have been made

by Sorby (1879), Wethered (1890 and 1895), Rothpeltz (1892), Vaughan (1914) and 1924), Eardley (1938), Mongahan and Lytle (1956), Illing (1954), Beales (1958) and Newell, Imbrie and Purdy (1960). The different theories of origin of ooids can be grouped into four major categories:

1) Inorganic precipitation of calcium carbonate needles onto pre-existing nuclei:
   Newell et al. (1960) suggest that the sea water which shoals over the Bahamian Platform is super-saturated with respect to calcium carbonate and with warming and agitation aragonite needles are precipitated onto pre-existing nuclei. Eardley (1938) supports the general inorganic precipitation theory of origin.
2) Algal attachment to pre-existing nuclei:
   Wethered (1890 and 1895) states that the microstructure of the oolitic envelope of many ooids closely resembles the tabular structure of the alga Girvanella or some alga akin to Girvanella but perhaps lower in the phylogenetic sequence. The presence of the algal structure in the oolitic envelope led Wethered to propose that the envelope is the result of algae attaching to and wrapping around pre-existing nuclei. During the formation of the envelope, the algae secrete calcium carbonate which fills the algal tubes and the spaces between the tubes to give a hard, solid envelope. Van Tuyl (1916) and Rothpletz (1892) support the general theme of this theory in that they report the presence of algal threads in oolitic envelope structures and state that their presence indicate that algae do play an important role in the formation of the envelopes.
3) Inorganic or organic precipitation of ooids from sea water:
   Vaughan (1914) claimed that he had produced ooids by direct precipitation from sea water (both nucleus and envelope); however, Vaughan (1924) later found that most of the grains produced in his laboratory experiments lacked the characteristic concentric laminations of ooids. Mongahan and Lytle (1956) produced ooids by both inorganic and organic precipitation of calcium carbonate from sea water in the laboratory.
4) Mechanical aggregation:
   Sorby (1879), Illing (1954) and Beales (1958) support the theory of the mechanical attachment of pre-existing calcium carbonate needles to pre-existing nuclei. In general, they feel that nuclei (almost any clastic grain type) which exist in a matrix of fine-grained aragonitic mud, will gather needles of the mud when they (the nuclei) are subjected to rolling around on the mud floor. The consensus among the proponents of mechanical aggregation is that the rolling around is the result of wave action.

Work done on modern carbonate sediments by Newell, Imbrie and Purdy (1960), Purdy (1960), Illing (1954) and Ginsburg (1956) indicates that ooids are formed in a highly-agitated, shallow, marine environment of not more than 30 feet in depth.

ORIGIN OF OOIDS IN THE SIGSBEE BLANKET

The ooids in the Sigsbee blanket occur through a depth range of 170 to 450 feet. This depth zone does not correspond to the general environmental conditions in which ooids are believed to form, that is agitated, shallow water with depths not exceeding 30 feet (Newell et al., 1960). The best interpretation of ooid occurrence in the 170 to 450 foot depth range on the Yucatan Shelf is that ooid formation and/or deposition is related to shallow-water conditions coincident with the low sea level stages of the Holocene trangression; in other words, the ooids are relict. A radiocarbon date of 13,780+200 years B.P. on ooids from the Sigsbee blanket indicates an age of formation no younger than early Holocene; the introduction of younger carbon may give an apparent age that is too young, and in the light of this, the ooid may have been formed (as opposed to deposited) as early as Wisconsin.

The wide, continuous occurrence of ooids in the area between the 170 and 450 foot isobaths suggests a general uniformity in environmental conditions throughout this area at the time of ooid deposition. The depth differential of 280 feet precludes a static environmental (sea level) regime and it is necessary to postulate a transgressive environment, with sea level rise between approximately -450 and -170 feet.

The limestones unconformably underlying the Sigsbee blanket in the depth zone between -170 and -300 feet are oosparites and pelsparites (Harding, 1963) and erosion of these rocks during the Holocene transgression has resulted in an abundance of oosparite and pelsparite lithoclasts in the Sigsbee blanket. As noted earlier, many of the individual ooids in the -170 to -300 foot depth zone have rims of blocky calcite crystals adhering to the periphery; these grains may also be considered as remanie, essentially a form of lithic fragment where the eroded limestone has been reduced to the individual allochems. In the depth zone between 300 and 450 feet, the Sigsbee blanket is unconformably underlain by a unit of Wisconsin age, the Campeche calcilutite, which contains pellets and rare ooids set in a matrix of aragonitic lutite (Logan, 1963). Some of the ooids in the Sigsbee blanket from this depth zone have adhering rims of aragonite micrite suggesting a source in the reworking of the Campeche calcilutite during transgression over that unit.

The evidence of adhering cements suggests that many of the ooids within the Sigsbee blanket are second cycle erosion products, derived by erosion of the underlying rocks and sediments during the passage of the advancing Holocene shoreline across the basal unconformity. The near shore or shoreline environment is also suitable for the formation of primary ooids and it is possible that some of the oolitic coatings were developed during the Holocene transgression, this is indicated by the occasional observation of oolitically-coated lithoclasts in Sigsbee blanket sediments. There is no way of assessing, either qualitatively or quantitatively, the proportion of primary Holocene ooids to second cycle ooids within the Sigsbee blanket.

NON-SKELETAL AGGREGATES

The aggregate category is composed of three types of grain: 1) grapestone aggregates, 2) mud aggregates and 3) undifferentiated cement aggregates.

Grapestone Aggregates

Grapestone aggregates are characterized by the random arrangement of ooids and/or pellets in an aggregation which is held together by a cement of fine-grained aragonite. The surface of the aggregate is characterized by protruding grains and re-entrants. These aggregates range in size from 0.50 mm to greater than 2.0 mm and usually have a rather dull luster.

Grapestone aggregates are randomly distributed in the Sigsbee blanket and occur as individual aggregates and as the nucleus of oolitic accretion. Grapestone aggregates occur in very few samples from the Sigsbee blanket and never account for more than 2% of the sand fraction.

Folk (1959) mentioned that grapestone aggregates could be formed as intraclasts. Illing (1954) suggested that the grapestone aggregates in the Bahamian sediments are formed by *in situ* aggregation of grains and Purdy (1960) suggested that the cementation of the aggregate may be the result of bacterial action on the organic matter in the interstial mud and the precipitation of aragonite from the intragranular water.

Mud Aggregates and Undifferentiated Cement Aggregates

Mud aggregates have the same optical properties and composition as micritic pellets but they have no regular outline or shape.

Undifferentiated cement aggregates are weakly-bound aggregates of shell fragments, ooids, pellets and/or whole shells. A binding material cannot be discerned under the microscope. These aggregates are sparsely distributed in the sediments of the Sigsbee blanket that were examined.

Illing (1954) reported friable aggregates in the Bahamian sediments and observed stages of aggregation ranging from these friable aggregates to the well-cemented and oolitically-coated aggregates (boytriodal lumps). Ginsburg (1956) proposed that Illing"s friable aggregates may be the result of laboratory processing (oven drying). Purdy (1960) states that both natural and laboratory processes can result in friable aggregates. The friable aggregates are similar in description to the undifferentiated cement aggregates of the Sigsbee blanket and a similar origin for the aggregates in the Sigsbee blanket or in our laboratory is certainly feasible.

ORIGIN OF NON-SKELETAL AGGREGATES IN THE SIGSBEE BLANKET

The aggregates present in the Sigsbee blanket sediments could be the product of natural or laboratory processes. The most durable aggregate is the grapestone aggregate in that it forms the nucleus for some oolitic accretion. This means that it must be durable enough to withstand the high energy environment that is associated with the oolitic accretion. The grapestone aggregates reported in modern sediments (Illing, 1954 and Purdy, 1960) occur in shallow, quiet-water environments where it is possible for the fine-grained carbonate to accumulate in the interstitial spaces. The writer feels that the few grapestone aggregates in the Sigsbee blanket could have been formed by a process similar to that described by Purdy (1960), or as intraclasts as described by Folk (1959).

The mud aggregates and undifferentiated aggregates could be formed by natural aggregation or by laboratory processing and there is no way to discern between the natural and artificial product.

LITHIC FRAGMENTS (LITHOCLASTS)

The lithic fragments or lithoclasts which occur in the Sigsbee blanket are sand-to pebble-size fragments of well-indurated limestone with flaky, irregular or rounded shape. Most of the grains are well-cemented and some have formed the nuclei for later development of oolitic coatings. Associated with lithoclasts are remanie fossils, mainly foraminifera and bryozoa, in which the skeletal cavities are filled with cement or matrix. The rock fragments are

considered to be erosion products of the underlying Wisconsin and pre-Wisconsin units derived as a type of "basal sand" during the advance of the Holocene shoreline across the unconformity. The lithoclasts in the Sigsbee blanket fall into two compositional suites corresponding to the sparite and micrite limestone types of Folk (1959).

Lithoclasts of Sparitic Composition

Lithoclasts belonging to the sparite group are rounded to irregular grains. The common lithology is that of grainstone with abundant allochems set in an interstitial cement of blocky calcite. The allochems are micritic pellets, ooids and occasional fragments of shallow-water foraminifera, coralline algae and mollusca (Plate III, fig. 1). Occasional crustacean faecal pellets are present as allochems and the characteristic drainage canals are often filled with blocky (sparry) calcite. The allochems are often truncated at the surface of the lithoclasts indicating that the fragment was subject to abrasion and was resistant at that time. Occasional remanie fossils are observed with infillings of sparry calcite and many ooids and pellets have blocky calcite adhering to the outer surfaces (Plate II, Fig. 6) suggesting that these grains have been broken out of relatively well-cemented sparitic limestones.

The oosparite, pelsparite and biosparite lithoclasts in the Sigsbee blanket are chiefly confined to a broad depth zone between the present 180 and 300 foot isobaths. Their occurrence in the Sigsbee blanket in this zone ranges from frequent to rare (Harding, 1963).

Lithoclasts of Micritic Composition

Lithoclasts of micritic composition are commonly flaky to irregular grains. The most common lithology of these lithoclasts is a grain-supported sediment with pellets, ooids and skeletal allochems set in a matrix of microcrystalline carbonate (micrite); some of the lithoclasts may be relatively pure micrite (Harding, 1963). The matrix may be either calcitic or aragonitic in composition. Allochems are often truncated as the lithoclast boundaries and occasional individual pellets and ooids are observed with adhering masses of microcrystalline carbonate on the periphery, suggesting that these grains have been broken out of a micritic matrix. The micritic lithoclasts range from very hard to relatively soft in resistance to pressure.

The micritic lithoclast group in the Sigsbee blanket is chiefly confined to the depth zone between the present 300 foot isobath and the 500 foot isobath on the outer shelf margin (Harding, 1963).

ORIGIN OF LITHOCLASTS IN THE SIGSBEE BLANKET

The lithoclasts in the Sigsbee blanket are the erosion products of sediments underlying this transgressive unit. The distribution of the micritic lithoclast suite in the unit corresponds to the general area of occurrence of the Campeche calcilutite, a Wisconsin formation underlying the Sigsbee blanket and to the mild unconformity which is developed on the upper surface of that unit. The micritic lithoclasts are lithologically similar to the sediments of the Campeche calcilutite and there can be little doubt that they have been derived from consolidated and semi-consolidated portions of that unit.

The sparitic lithoclasts occur in a zone where the Sigsbee blanket is underlain by rock--between the 180 foot and 300 foot isobaths. These well-cemented lithic fragments are the product of the erosion of underlying rock during the post-glacial transgression.

ALGAL FRAGMENTS

The algal fragment category is composed of skeletons of carbonate secreting algae such as Halimeda, Lithothamnium, Lithophyllum, and Amphioroa. The fragments range in length from 0.50 mm to greater than 2.00 mm and are platy to stem-shaped. Halimeda plates are dark-gray to brown in plane polarized light and exhibit tubular, thread-like microstructure. The coralline algae are identified by the presence of tissue structure in the fragments. In some instances, secondary aragonite has been observed as infilling in the cells and conceptacles of the coralline algae.

The algal fragments occur as individual grains and as allochems in some lithic fragments. They occur in most of the samples taken from above the shelf-edge break in percentages ranging from 1% to 35% of the sand fraction. In general the algal component of the sand fraction is more abundant in the depth zone between -400 feet and -170 feet than in the depth zone between the 400 foot and 660 foot isobaths. The highest percentages are found in the depth zone between -240 feet and -170 feet.

The algal fragments in the sediments of the Sigsbee blanket are the remains of lime-secreting algae. The algae need light to grow and flourish and therefore are usually found living in water less than 180 feet deep. The largest algal community, on the Yucatan Shelf, occurs in and around the reef top and in the lagoonal areas of the marginal reefs.

ORIGIN OF ALGAL FRAGMENTS
IN THE SIGSBEE BLANKET

Since the shallowest occurring algal fragments in the sediments of the Sigsbee blanket appear near the lower limit of the living depth range of the contributing species, the majority of this material may be a product of the lower sea levels of Holocene time. There is also a possibility that some of the fragments have deposited as a shed from the organic communities which cap the marginal hills.

BENTHONIC FORAMINIFERA

The benthonic foraminiferal category has been divided into two sub-categories; 1) calcareous benthonic foraminifera and 2) agglutinate foraminifera.

Calcareous Benthonic Foraminifera

The calcareous benthonic foraminifera are represented by *Amphistegina*, miliolids, and peneroplids (Plate III, figs. 4 and 6). The tests range in size from 1.00 mm to 2.00 mm. In thin section, *Amphistegina* tests are identified by their shape, internal structure (chambers) and the closely-spaced perforations in the wall of the tests. The test of miliolid foraminifera are identified by their characteristic chamber arrangement, they usually also exhibit a brown to yellowish-brown color in plane polarized light. The peneroplid tests are recognized in thin section by the mesh-like network of chamberlets and the yellowish-brown color of the test wall.

Amphistegina and miliolid tests usually occur whole, although some fragmented *Amphistegina* tests have been observed in the samples. According to Harding (1963) tests of *Amphistegina* also occur as allochems in some of the larger lithic fragments (greater than 2.00 mm). Peneroplid tests occur as whole tests and as fragments of tests in the sand fraction of the Sigsbee blanket. Many of these tests are infilled with secondary carbonate.

The calcareous benthonic foraminifera range from 1% to 17% in the sand fraction and they occur in the majority of the samples taken from the Sigsbee blanket. This particular group of tests seem to be more abundant in sediments from the depth zone between -180 feet and -450 feet than in the zone between the 450 foot isobath and the shelf-edge break.

Agglutinate Foraminifera

The agglutinate foraminifera (Plate III, fig. 5) range in size from 0.5 mm in cross-sectional diameter to greater than 1.0 mm in length. Both sand and silt-size particles are cemented into the tests. The non-random arrangement of the agglutinated grains and the presence of chambered structure were used as criteria for identification in thin section. A major portion of the agglutinate foraminiferal tests belong to the family Textulariidae.

The agglutinate foraminiferal tests are more widely distributed with respect to depth than the calcareous benthonic foraminiferal tests and occur in samples from about -720 feet to -170 feet in percentages ranging from 1% to 25% of the sand fraction.

ORIGIN OF BENTHONIC FORAMINIFERAL TESTS IN THE SIGSBEE BLANKET

The tests that compose the calcareous benthonic foraminiferal fraction are the product of a shallow-water benthonic foraminiferal fauna. The following tests have been identified from the sediments of the Sigsbee blanket:

1) *Amphistegina lessonii* (d'Orbigny)--living depth range of from 0 to 300 feet (Phleger and Parker, 1951)
2) *Quinqueloculina compta* (Cushman)--living depth range of from 30 to 60 feet (Phleger, 1960)
3) *Archais compressus* (d'Orbigny)--living depth range of from 0 to 110 feet (Phleger and Parker, 1951).

These foraminiferal tests occur in an area that ranges from 180 to 600 feet in depth and are obviously outside the living depth range of the contributing species. They can be explained as products of lower sea level conditions.

The agglutinate foraminiferal tests in the sediments of the Sigsbee blanket generally belong to the family Textulariidae with a large portion of the tests belong to the genus *Textularia*. The living depth range of these organisms is wider than that of the calcareous benthonic foraminifera, ranging from 0 to about 900 feet. According to Phleger (1960) agglutinate forms are present in significant quantities in both lagoonal and open ocean environments.

BENTHONIC SKELETAL FRAGMENTS

This category of grains is composed of skeletal fragments of mollusks, corals, bryozoa and echinoids. In thin section, the

molluscan fragments exhibit the typical cross laminar structure that is characteristic of shells in this phylum. The coral fragments are characterized by a radial or fibrous microstructure that exhibits a wavy extinction under crossed nicols. The bryozoan fragments are characterized by an open meshwork or lace-like structure and the echinoid fragments can be identified by the net-like microstructure of the plates and the unit extinction exhibited by both plates and spines under crossed nicols.

Benthonic skeletal fragments occur in the sand fraction of the Sigsbee blanket as individual grains in percentages ranging from 3% to 74% and are also present as allochems in some of the lithic fragments. Molluscan and coral fragments are the dominant types encountered in these sediments. The echinoid fragments are randomly-distributed throughout the unit and usually compose less than 15% of the sand fraction. Bryozoan fragments are rare in the sediments from the Sigsbee blanket.

ORIGIN OF BENTHONIC SKELETAL FRAGMENTS IN THE SIGSBEE BLANKET

The shell fragments that occur in the Sigsbee blanket are the hard parts of animals that once lived, and in some cases, are living in the area of occurrence.

PLATE I

PHOTOMICROGRAPHS OF CALCAREOUS PELLETS AND OOIDS FROM THE SIGSBEE BLANKET

Figure 1--Longitudinal section of micritic pellet with peripheral rim of clear, indeterminate material, crossed nicols, X 100.

Figure 2--Oblique section of superficial ooid with tangentially-oriented aragonite needles forming the envelope, crossed nicols, X 100.

Figure 3--Longitudinal section of semi-mature ooid, crossed nicols, X 100.

Figure 4--Cross section of mature ooids, note both radially and tangentially arranged needles in the envelope, crossed nicols, X 60.

Figure 5--Two-stage ooid, crossed nicols, X 100.

Figure 6--Oolitically-coated grapestone aggregate illustrating the infilling of the re-entrants by the envelope, crossed nicols, X 30.

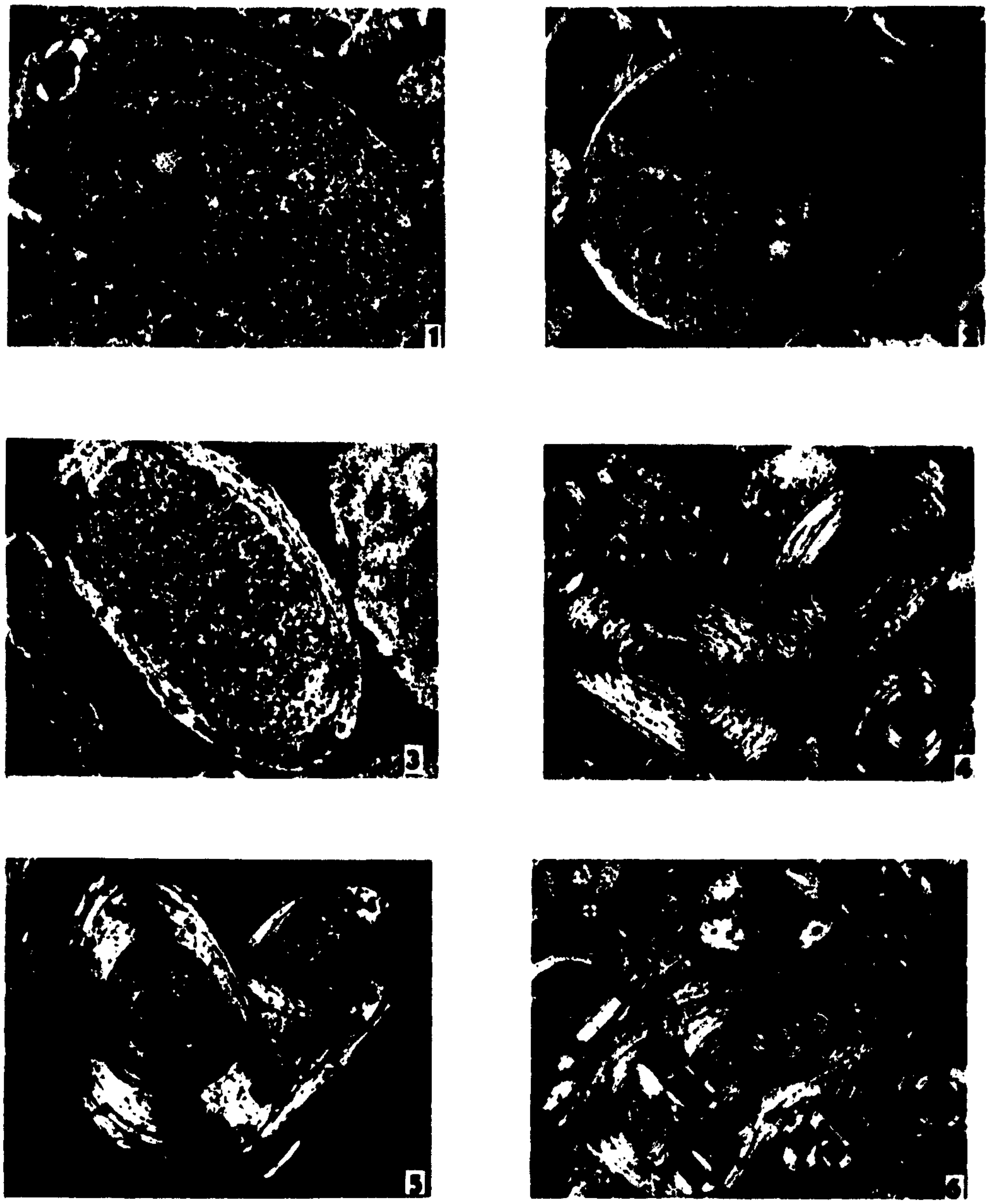


PLATE I

PLATE II

PHOTOMICROGRAPHS OF CALCAREOUS PELLETS AND LITHOCLASTS IN THE SIGSBEE BLANKET

Figure 1--Longitudinal section of crustacean faecal pellet, exhibiting drainage canals as dark strips, crossed nicols, X 100.

Figure 2--Longitudinal section of arenaceous pellet, coarser material concentrated from the center of pellet along with some darker colored material, crossed nicols, X 100.

Figure 3--Longitudinal section of crustacean faecal pellet, exhibiting drainage canals partially filled with sparry calcite and some smaller ingested micritic pellets and ooids, crossed nicols, X 45.

Figure 4--Cross section crustacean pellet exhibiting crescent-shaped drainage canals and bilaterally symmetrical arrangement, crossed nicols, X 100.

Figure 5--Oomicrite lithic fragment with transected allochems near top of fragment indicating abrasion, crossed nicols, X 30.

Figure 6--Ooid with relict cement, X 75.

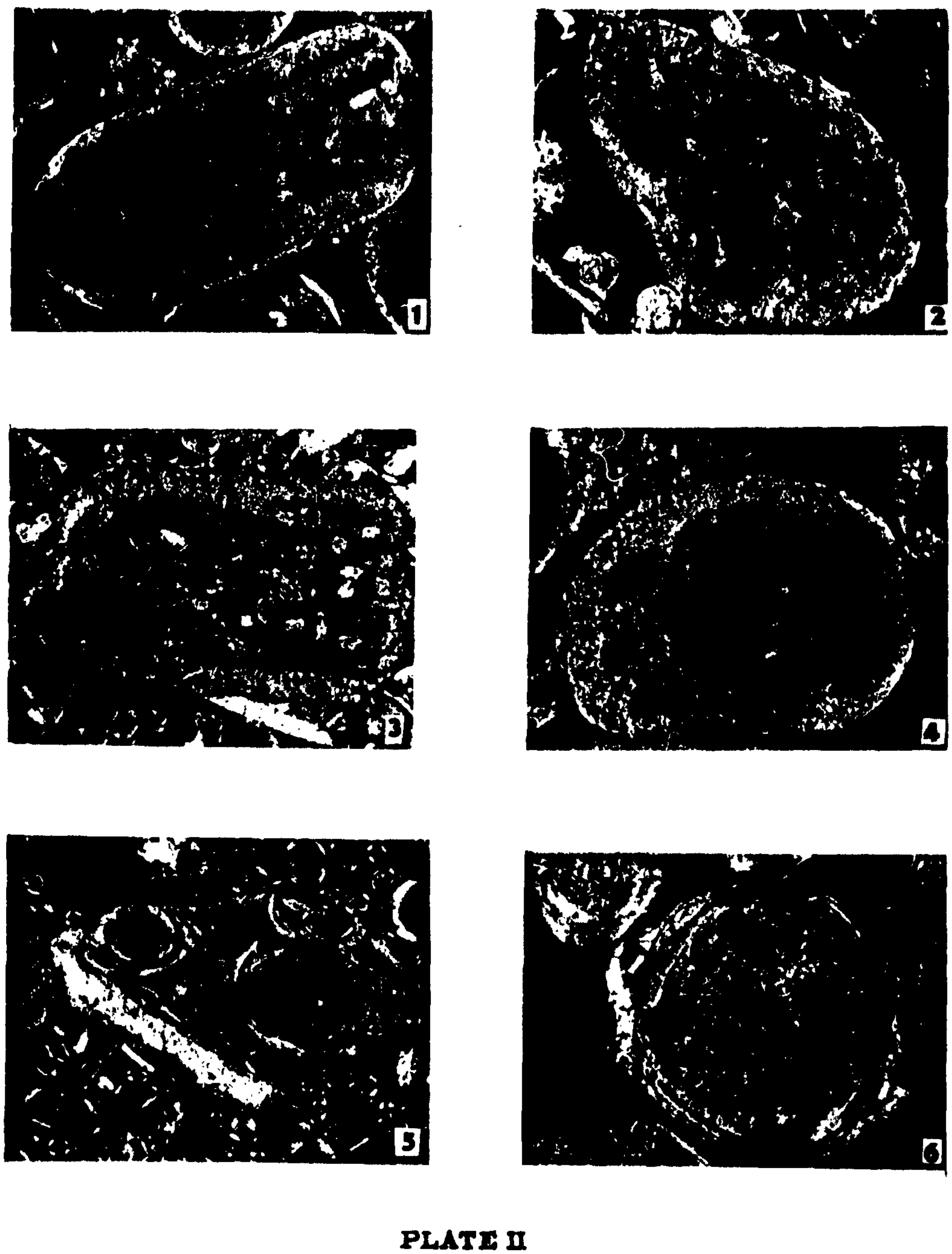


PLATE II

PLATE III

PHOTOMICROGRAPHY OF LITHOCLASTS AND SKELETAL FRAGMENTS FROM SIGSBEE BLANKET

Figure 1--Oosparite lithic fragment, cement is blocky calcite, crustacean pellet near top of figure also has drainage canals filled with calcite, crossed nicols, X 60.

Figure 2--Coralline algal fragment, exhibiting tissue microstructure and secondary aragonite in cavities, crossed nicols, X 20.

Figure 3--Planktonic foraminiferal test, exhibiting globular shape of test and typical foraminiferal perforations, crossed nicols, X 100.

Figure 4--*Amphistegina* test, exhibiting test shape, heavy wall structure and closely-spaced wall perforation, crossed nicols, X 45.

Figure 5--Agglutinate foraminiferal test, exhibiting agglutinated grains arranged around chambered structure of the foram, crossed nicols, X 30.

Figure 6--*Archais compressus* test, exhibiting chamberlet microstructure and yellowish-brown color, crossed nicols, X 15.

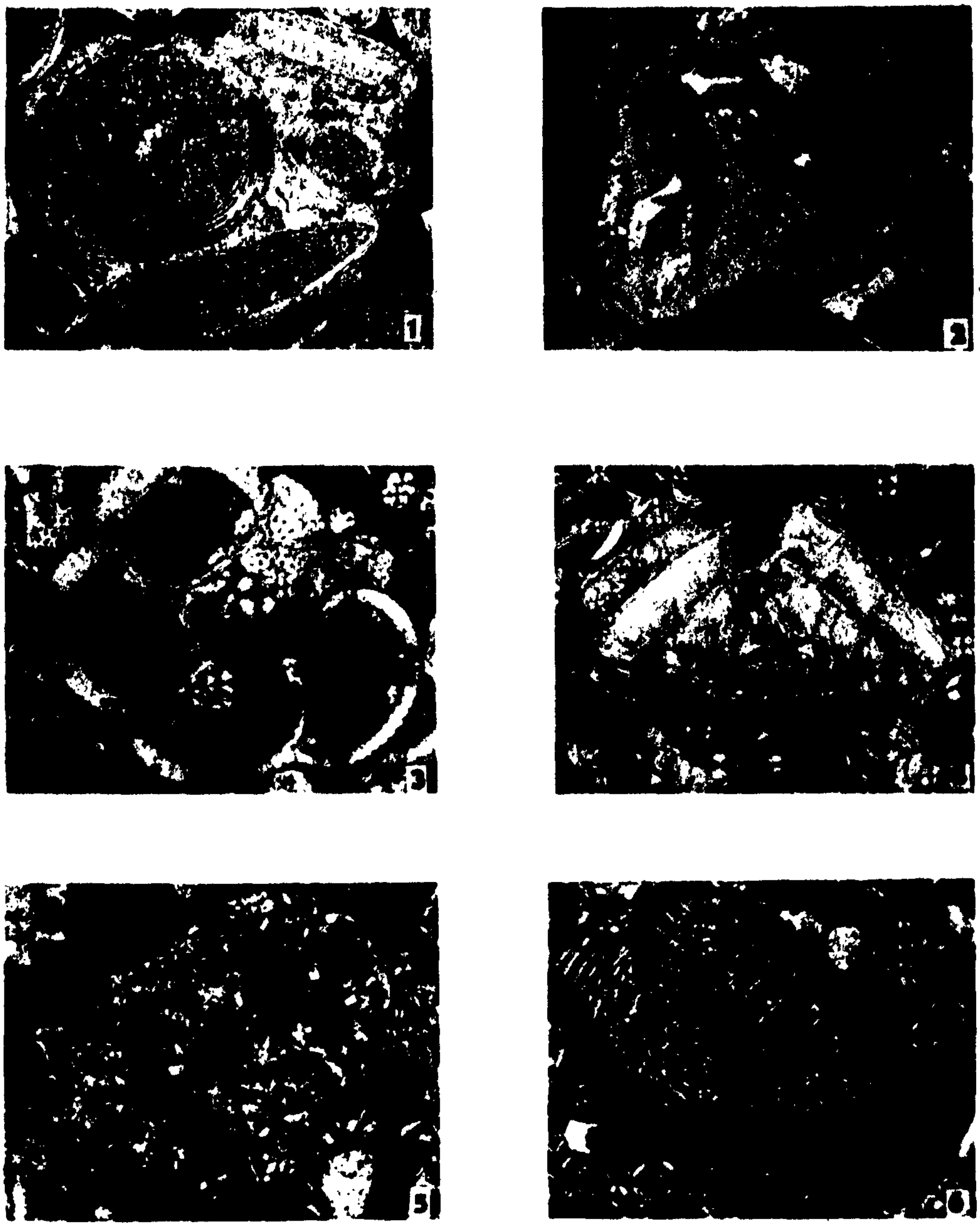


PLATE III

CHAPTER VII

FACIES IN THE SIGSBEE BLANKET

A lithofacies is defined as a lateral sub-division of a stratigraphic unit which is differentiated from adjacent sub-divisions by its lithological character (Weller, 1960). In the study of unconsolidated sediments, the prefix litho- is usually dropped in favor of the term facies. The upper and lower boundaries of a facies correspond to the limits of the stratigraphic unit in which it is contained. A facies may be distinguished from other adjacent facies within the unit qualitatively on the basis of general lithological characteristics or quantitatively at arbitrary chosen statistical boundaries.

The stratigraphic unit in this study is the Sigsbee blanket and it contains four facies which are:

1) Ooid-pellet calcarenite facies--composed of sediments of textural compositional group I. This facies lies between the benthonic skeletal calcarenites on the inner shelf and the silty, planktonic, ooid-pellet calcarenite facies. The distinction between the ooid-pellet calcarenite facies and the inner shelf sediments is based on a non-skeletal/benthonic skeletal grain ratio greater than 0.25. The distinction between the ooid-pellet calcarenite facies and the adjacent silty, planktonic, ooid-pellet calcarenite facies is equivalent to the distinction made between textural/compositional groups 1 and 2.
2) Silty, planktonic, ooid-pellet calcarenite facies--composed of sediments of textural/compositional group 2.
3) Silty, planktonic, pelletal calcarenite facies--composed of sediments of textural/compositional group 3.
4) Planktonic calcilutite facies--composed of sediments of textural/compositional group 4.

In this study, facies are the units of a formation and have a definite spacial inter-relationship. These facies are important in the description of the Sigsbee blanket and to the interpretation of its depositional history. The four facies contained in the Sigsbee blanket are distributed in broad zones that parallel the bathymetric contours of the Yucatan Shelf (fig. 9). Facies relationships are summarized in Table I.

OOID-PELLET CALCARENITE FACIES

The ooid-pellet calcarenite facies is a portion of the Sigsbee blanket characterized by sediments of textural/compositional

group 1.

The ooid-pellet calcarenite facies extends as a thin, blanket-like deposit from the vicinity of the 240 foot isobath landward to the 180 foot isobath and is then extended as tongue-like projections onto the inner shelf between the marginal inorganic banks and reefs to the 170 foot isobath. The facies width between the 240 and 180 foot isobaths ranges from 1 to 8 miles. The distribution of the facies corresponds to the -170 to -210 foot submerged terrace which is believed to be a wave cut feature possibly related to a small hesitation and/or reversal in the Holocene transgression (Logan, 1962). The ooid-pellet calcarenite facies is on the order of 3 inches to 1 foot in thickness and unconformably overlies a surface of hard, cemented limestones of possible Wisconsin or pre-Wisconsin age. According to Harding (1963) the limestones are sparites with allochems of ooids, pellets and skeletal grains.

The sediments of the ooid-pellet calcarenite facies grade laterally into benthonic skeletal calcarenites on the inner shelf floor between the 150 and 180 foot isobaths by a gradual shoreward decrease in percentage of non-skeletal grains. The shallow, landward boundary of the unit (facies) is arbitrarily based on a non-skeletal/benthonic skeletal grain ratio of 0.25. Some gradational samples fall into textural group 1 on the basis of grain size but they are of different composition being composed of 70% to 90% benthonic skeletal fragments and corresponding lesser amounts of non-skeletal particles.

The sediments of the ooid-pellet calcarenite facies occur on the shelf floor adjacent to the bases of the inorganic banks which form the foundation for reef and biostromal development in the Yucatan area. In most cases, the ooid-pellet calcarenites are sharply delineated from the biostromal algal-foraminiferal nodules which occur on the flanks of the rocky banks at a boundary corresponding to the position of the 170 foot isobath. The ooid-pellet calcarenite facies sediments occur on the leeward side of the large Alacran reef complex (Kornicker and Boyd, 1962). There is a small lee-ward, off-reef drape of fine skeletal sands (corals, coralline algae, Halimeda, etc.) extending 0.5 to 1.0 mile from the leeward reef wall onto the shelf floor. These finer sediments, which have been transported from the reef lagoon (Logan, 1963) are gradational into the ooid-pellet calcarenite facies and in some cases are admixed with those sediments to produce sediments finer than the normal textural/compositional group 1 type.

ORIGIN OF THE OOID-PELLET CALCARENITE FACIES

The seafloor on which the sediments of the ooid-pellet calcarenite facies occur, is presently submerged to depths between

170 and 240 feet. The water-sediment interface is below normal wave base in the Yucatan region (Walsh, 1962) and may be considered as a low energy, outer shelf environment subject only to agitation during severe storms. The gross aspect of the ooid-pellet calcarenite facies sediments suggests an environment of formation or deposition unlike the environment of modern occurence. Ooids are generally formed in shallow, agitated water less than 30 feet in depth (Newell et al., 1960); second cycle ooids, pellets and remanie fossils indicate erosion of the rocks underlying the unconformity in relatively high energy, wave zone or near-wave zone conditions; the most extensive deposits of modern calcareous pellets occur in environments with depths less than 100 feet (Illing, 1954; Purdy, 1960 and Kornicker and Purdy, 1957). The skeletons of the benthos in the ooid-pellet calcarenite facies are generally outside the depth range for most of the living species (0 to 180 feet). It is therefore evident that the ooid-pellet calcarenite facies sediments are not adjusted to the present environment but are the product of an earlier, high to medium energy environment, possibly littoral and sublittoral in position. This type of environment, on the Yucatan Shelf, is presently limited to the shorelines of the Yucatan Peninsula within the 0 to 60 foot depth range and to the reef fronts.

It has been noted that the ooid-pellet calcarenite facies distribution corresponds closely to the submerged shoreline terrace at -170 to -210 feet. This terrace is believed to have been cut into rock during a small hesitation and possible slight regression in the Holocene transgression. The absolute age of the 170 to 210 foot terrace is not known with certainty. Calculation from the sea level/time curves of Shepard (1960) suggest that this feature may have been formed, or the Holocene sea level coincided with the position of the terrace at approximately 12,000 years B.P. From the relationship to the terrace, the maximum age of the ooid-pellet calcarenite facies deposition (as opposed to formation) may be placed in a range of 8,000 to 12,000 years B.P. or early Holocene.

SILTY, PLANKTONIC, OOID-PELLET CALCARENITE FACIES

The silty, planktonic, ooid-pellet calcarenite facies is an areally circumscribed portion of the Sigsbee blanket composed of sediments which fall into textural/compositional group 2. The sediments are a polygenetic admixture of the ooid-pellet calcarenites of group 1 and the planktonic calcilutites of group 4. They represent the products of at least two diverse, depositional environments which have been admixed by post-depositional processes to form a body of homogeneous sediments. The facies presently occurs in a broad depth zone between the 240 foot and 450 foot isobaths. The width of the facies band varies from 5 to 12 miles depending upon the inclination of the underlying unconformity.

The silty, planktonic, ooid-pellet calcarenite facies extends as a thin blanket-like deposit across the upper outer shelf and outer shelf terrace bathymetric sub-divisions. The blanket ranges from 1 to 4 feet in thickness with thinning on small topographic highs and thickening in local depressions of the underlying surface. In the depth zone between the 240 and 300 foot isobaths the facies rests on an erosional surface which is developed on sparitic limestones (oosparites, pelsparites and biosparites). In the depth zone between the 300 foot and 450 foot isobaths (the submerged Wisconsin terrace of Logan, 1963), the facies overlies semi-consolidated sediments of the Campeche calcilutite, a Wisconsin unit which underlies the terrace and the shelf to seaward. The contact between the Sigsbee blanket and the Campeche calcilutite is interpreted as an erosional unconformity in the 300-450 foot depth area.

The boundaries of the silty, planktonic, ooid-pellet calcarenite facies are marked by gradation into adjacent facies within the Sigsbee blanket. The seaward boundary occurs in the vicinity of the 450 foot isobath, where the ooid, pellet, lithic fragment fraction of the group 2 sediments give way to a non-skeletal fraction dominated only by calcareous pellets typical of textural/compositional group 3. The landward boundary of the facies blanket is a gradation to sandy, group 1 (ooid-pellet calcarenite facies) sediments in the vicinity of the 240 foot isobath. This boundary is arbitrarily chosen on the percentage of planktonic silt with the shallower ooid-pellet calcarenite facies sediments having less than 10% silt-size particles.

ORIGIN OF THE SILTY, PLANKTONIC, OOID-PELLET CALCARENITE FACIES

It has been shown that the non-skeletal and benthonic skeletal calcarenite fraction of group 1 and group 2 sediments are lithologically identical and therefore they should have a similar depositional environment, that is, a transgressive shallow-water environment. Above the 300 foot isobath, many of the ooids and pellets have relict sparry cement associated with them while below the 300 foot isobath the only relict cement seen on ooids and pellets is micritic. This change in relict cement can be correlated with a difference in substratum, in that, the underlying material in the depth zone between the 300 foot and 240 foot isobaths is sparitic limestone. In contrast the Campeche calcilutite, a semi-consolidated micrite, occurs seaward of the 300 foot isobath. There is a possibility that the ooids seaward of the 300 foot isobath are of primary origin rather than erosional products of the Campeche calcilutite because very few ooids have any sort of relict cement and Ahr (1963) reports that the Campeche calcilutite is peiletal as opposed to oolitic in this area. It is conceivable that ooids were formed in the high energy environment which transgressed the area in post glacial time and were left as a sandy deposit lying on the surface of the unconformity between the Sigsbee blanket facies and the Campeche calcilutite.

The planktonic component of the silty, planktonic, ooid-pellet calcarenite closely resembles the group 4 sediments (planktonic calcilutite) and is independent of the non-skeletal and benthonic skeletal portion of the sediments of this facies. The addition of the planktonic component is the result of the progressive deepening of the depositional interface with the progressive rise of sea level in post-glacial time. Post-depositional processes, animal burrowing and occasional mechanical stirring by hurricane waves, have admixed the two sediment types and have given the sediment a mottled to homogeneous appearance.

SILTY, PLANKTONIC, PELLETAL CALCARENITE FACIES

The silty, planktonic, pelletal calcarenite facies is a portion of the Sigsbee blanket composed of sediments which fall into textural/compositional group 3. The sediments are polygenetic admixtures of a non-skeletal and benthonic skeletal calcarenite and the planktonic calcilutite described as textural/compositional group 4. They are the products of at least two environments of deposition.

The silty, planktonic, pelletal calcarenite facies forms a thin blanket-type deposit, 1 to 3 feet thick on the western margin in a broad band approximately contained by the 450 foot and 540 foot isobaths (fig. 9), extending from near the submerged hills on the northeastern part of the Yucatan Shelf to near 21° north latitude. The silty, planktonic, pelletal calcarenite facies overlies the unconsolidated Campeche calcilutite with what appears to be a mild disconformity (Logan, 1963). This contact may be a wave erosion feature of late Wisconsin age since it grades into a stronger unconformity on the outer shelf terrace (-300 to -450 feet) and into a conformable contact near the shelf slope-break (-600 to -660 feet).

The boundaries of the silty, planktonic, pelletal calcarenite facies are gradational contacts between adjacent facies in the Sigsbee blanket. The landward boundary is a gradation into the silty, planktonic, ooid-pellet calcarenite facies (occurring in the vicinity of the 450 foot isobath). The seaward boundary is a gradation into the planktonic calcilutite facies.

ORIGIN OF THE SILTY, PLANKTONIC PELLETAL CALCARENITE FACIES

The independence of the planktonic components and the non-skeletal and benthonic skeletal components indicate that the silty, planktonic, pelletal calcarenite facies is also a polygenetic admixture of two or more diverse sediment types. The possibility of

pellet formation as intraclasts has some support in this region in that the presence of a submarine disconformity between the underlying Campeche calcilutite and this facies suggests that the mechanism (wave base erosion) and the material (aragonitic micrite of the Campeche calcilutite) were available for the production of pellets as intraclasts. The logical time for the formation of pellets, in this area (-450 to 540 feet), as intraclasts or for the reworking of pellets from the Campeche calcilutite could have been subjected to wave base erosion.

The continuity of the non-skeletal and benthonic skeletal portions of the ooid-pellet calcarenite facies; the silty, planktonic, ooid-pellet calcarenite facies and the silty, planktonic, pelletal calcarenite facies leads the author to propose that the non-skeletal portion of the silty, planktonic, pelletal calcarenite facies can best be explained as nearshore, seaward deposit laid down penecontemporaneously with the deposition of the ooid-pellet calcarenite sediments which now extend to landward in a transgressive manner. The planktonic component of this facies can be explained as a later addition to the depositional interface that has resulted from the progressive deepening of that surface.

PLANKTONIC CALCILUTITE FACIES

The planktonic calcilutite facies is a portion of the Sigsbee blanket composed of sediments of textural/compositional group 4. The sediments are almost entirely composed of planktonic tests and shells. The facies extends as a thin blanket 1 to 3 feet in thickness through a broad zone extending seaward from the 540 foot isobath on the outer shelf margin, down the continental slopes and possibly onto the floor of the Sigsbee Deep (see Ewing et al., 1958). The planktonic facies grades laterally into the sediments of the silty, planktonic, pelletal calcarenite facies in the vicinity of the 540 foot isobath.

The upper boundary of the planktonic calcilutite facies is the modern sediment-water interface. The stratum overlies the Campeche calcilutite with conformity.

ORIGIN OF THE PLANKTONIC CALCILUTITE FACIES

The sediments of the planktonic calcilutite facies occur in a depth zone below the level of glacial maximum low sea level at

-450 feet. During the Wisconsin stage the shoreline was adjacent to the shelf margin and a good deal of shallow-water sediment was carried to the area and deposited along with planktonic shells and tests to form the Campeche calcilutite. During the post-glacial period the depositional interface has been subject to progressive deepening and a decline in the influx of detrital carbonate sediments. The deep-water and shallow-water carbonate sediment admixtures of the Campeche calcilutite give way to a relatively pure, deep-oceanic, sediment-type--the planktonic calcilutite or ooze of the Sigsbee blanket. Radiocarbon dates on planktonic shells and tests from the planktonic facies of the Sigsbee blanket are:

1) 10,570±300 years B.P. on shells from an interval 11-16 cm from the top of core 715 which was taken on the continental slope. The sample comes from the base of the Sigsbee blanket planktonic calcilutite facies, immediately above a gradational contact with the underlying Campeche calcilutite,
2) 2760±700 years B.P. on planktonic sediments from core 27 on the continental slope toward the top of the Sigsbee blanket, planktonic calcilutite facies.

The planktonic calcilutite facies is a typical oceanic deposit which is generally formed in areas of low detrital influx. Plankton-rich sediments of Holocene age are also reported from the Sigsbee Deep (Ewing *et al.* 1958) and from the continental slopes of Yucatan (Creager, 1958). The planktonic component of group 3 (silty, planktonic, pelletal calcarenite facies) and group 2 (silty, planktonic, ooid-pellet calcarenite facies) is similar to the pure end member (group 4) seen in the planktonic calcilutite facies. These sediments are younger than the shallow-water sands with which they are admixed. The encroachment of the planktonic environment onto the shelf and over the earlier sediment has followed the Holocene transgression.

PLATE IV

PHOTOMICROGRAPHS OF SAND FRACTIONS OF TYPICAL FACIES SEDIMENTS FROM THE SIGSBEE BLANKET

Figure 1--Planktonic calcilutite facies from the continental slope, crossed nicols, X 25.

Figure 2--Silty, planktonic, pelletal calcarenite facies from the outer shelf margin, crossed nicols, X 25.

Figure 3--Silty, planktonic, pelletal, calcarenite facies from the outer shelf terrace, crossed nicols, X 30.

Figure 4--Silty, planktonic, ooid-pellet calcarenite facies from the outer shelf terrace, crossed nicols, X 30.

Figure 5--Ooid-pellet calcarenite facies from the upper outer shelf, crossed nicols, X 30.

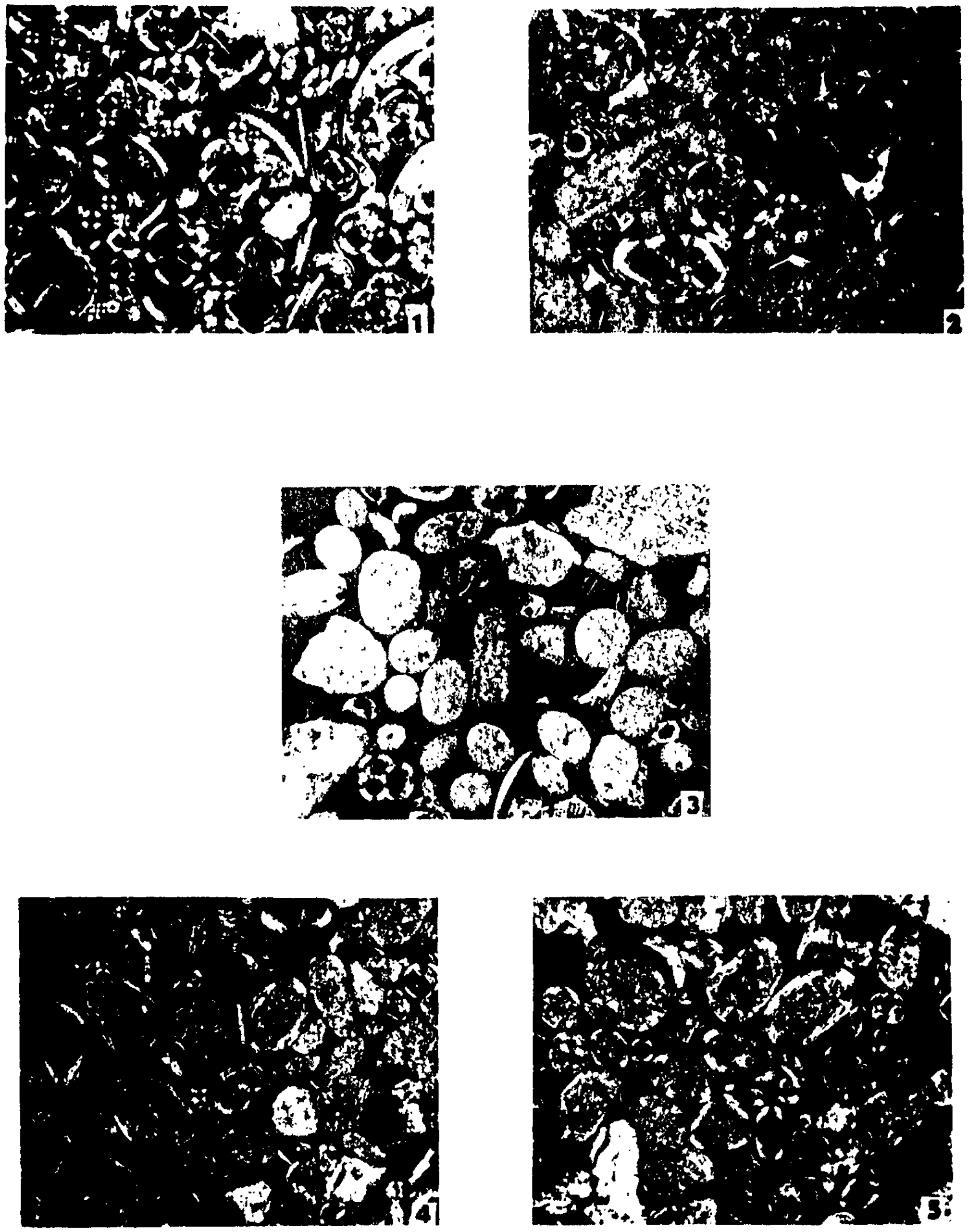


PLATE IV

TABLE I

RELATIONSHIPS OF SIGSBEE BLANKET FACIES

Facies	Texture and Composition	Compositional Relationships	Lower Contact of Facies	Depth Range of Occurrence (feet)	Bathymetric Location	Width (miles)	Thickness (inches)
Ooid-Pellet Calcarenite Facies	Textural/Compositional Group 1	Textural/Compositional Group 1	Unconformity on cemented limestone	170 to 240	Upper Outer Shelf and Inner Shelf	1 to 8	3 to 12
Silty, Planktonic, Ooid-Pellet Calcarenite Facies	Textural/Compositional Group 2	Admixture of textural/compositional Groups 1 and 4	Unconformity on cemented limestone and Campeche calcilutite	240 to 450	Upper Outer Shelf and Outer Shelf Terrace	5 to 12	12 to 48
Silty, Planktonic, Pellet Calcarenite Facies	Textural/Compositional Group 3	Admixture of pelletal calcarenite and textural/compositional Group 4	Disconformity on Campeche calcilutite	450 to 540	Outer Shelf Margin	1 to 3	12 to 36
Planktonic Calcilutite Facies	Textural/Compositional Group 4	Textural/Compositional Group 4	Conformity on Campeche calcilutite	540 to <1200	Outer Shelf Margin and Continental Slope	Undetermined	1 to 36

CHAPTER VIII

CONCLUSIONS

Several conclusions concerning the sediments of the Sigsbee blanket can be made--these are:

1) The sediments of the Sigsbee blanket are restricted to the outer shelf and continental slope provinces of the Yucatan Platform.
2) These sediments range from shoreline to deep-sea in lithological aspect.
3) The shallow-water sediment types are not genetically related to the deep-water sediment types.
4) The shallow water sediment types are the product of the shallow-water environment that was associated with the lower sea levels of post-glacial time.
5) The substrate has influenced the lithological aspect of the unit by contributing certain types of lithic fragments and also as a source for some of the other grain types such as ooids and pellets.
6) The broad zonal banding of the facies types in the Sigsbee blanket reflect the effect of the post-glacial transgression and the substrate lithology.
7) The planktonic calcilutite facies has encroached upon the previously deposited shallow-water sediment types to the vicinity of the 240 foot isobath with the transgression.
8) Post-depositional admixing by burrowing organisms and occasional stirring by hurricane waves has probably admixed the different sediment types and given the unit a homogeneous mottled appearance.

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APPENDIX I

EXPLANATION OF APPENDIX I

The following table illustrates the results of 100 point counts made by the author on samples from the Sigsbee blanket. Approximately 15 other point counts were made on samples that later proved to be included in another sedimentary unit, these are not included in the table.

The column headings are self-explanatory with the exception of "skeletal fragment" column. This column includes all shell fragments, coral fragments and algal fragments. The aggregate and indeterminates were omitted because of their minor contribution when compared to the categories represented in Table I. The numbers in the columns represent the percentages to the nearest 0.5%.

POINT COUNT RESULTS

Sample no.	Pellet	Ooid	Planktonic tests	Skeletal fragments	Benthic forams	Lithic fragments
315	13.5	3.5	----	68.5	14.0	2.0
316	13.5	21.5	1.5	35.5	15.5	10.5
317	22.0	21.0	11.5	18.0	9.5	9.0
428	34.0	9.0	0.5	44.5	8.5	3.0
429	39.5	17.5	----	21.5	1.5	19.0
430	18.5	10.5	2.5	28.5	1.5	38.0
433	34.0	17.5	----	26.5	----	19.5
434	35.5	2.5	1.7	30.0	13.5	11.5
437	15.0	2.5	2.0	68.5	9.5	.5
450	25.5	10.0	1.0	49.5	7.5	3.5
452	20.5	----	8.5	66.5	----	----
454	17.0	8.5	1.5	55.5	7.0	8.0
457	7.5	5.0	1.0	71.0	13.0	1.5
462	38.0	27.5	5.0	19.0	6.0	3.0
465	8.5	11.5	3.5	72.0	2.0	1.0
468	27.5	7.5	24.0	21.0	13.0	1.5
469	32.5	----	29.5	24.5	15.0	----
470	17.0	25.0	14.0	21.0	14.5	7.5
471	27.5	26.5	6.0	30.5	5.5	3.5
473	59.0	11.5	5.5	14.5	7.5	2.5
715	23.5	2.5	27.0	25.5	12.0	7.5
716	11.5	1.5	63.5	3.5	8.5	2.0
717	16.5	23.0	12.5	26.0	9.5	5.0
718	7.0	20.0	2.5	45.0	16.5	6.5
1251	----	----	90.0	7.0	----	2.0
1252	6.0	----	78.0	12.0	3.0	----
1253	35.0	0.5	25.0	24.0	5.0	6.0
1254	60.0	----	22.0	13.0	4.0	0.5
1255	52.0	3.0	29.0	5.0	9.5	0.5
1256	38.0	15.0	30.0	8.5	5.5	0.5
1257	30.0	11.0	24.0	19.0	16.0	----
1258	7.5	5.0	25.0	23.5	16.5	19.0
1259	21.0	52.0	----	16.0	----	11.0
1260	47.0	21 0	7.0	21.5	1.0	0.5
1261	15.0	9.5	5.5	33.0	1.3	24.0
1262	10.0	19.0	24.0	17.0	12.0	17.5
1263	25.0	21.5	26.0	10.0	13.0	3.0
1264	57.0	1.5	20.0	11.0	4.5	5.0
1265	46.5	2.0	22.0	15.3	8.0	5.5
1266	1.0	----	85.0	9.0	2.0	----
1267	5.5	----	80.5	9.5	1.0	----
1268	19.0	1.0	56.0	16.0	3.0	4.3
1269	46.0	8.0	30.0	11.0	1.5	2.0
1270	28.5	6.5	34.5	19.0	10.0	0.5
1271	15.0	30.0	9.5	25.0	6.5	7.5
1273	19.5	9.0	2.5	61.0	2.3	10.0

POINT COUNT RESULTS (Continued)

Sample no.	Pellet	Ooid	Planktonic tests	Skeletal fragments	Benthic forams	Lithic fragments
1278	17.0	12.5	0.5	31.0	4.0	35.0
1279	23.0	40.0	1.5	17.0	4.0	12.5
1280	14.0	21.0	24.5	20.0	10.5	----
1281	20.5	15.5	21.5	15.5	12.0	14 0
1284	3.5	----	70.5	8.0	1.5	17.0
1285	0.5	----	93.0	1.5	3.5	1.5
1286	5.0	----	76.5	12.5	6.0	----
1287	15.5	2.0	29.0	18.0	22.5	8.0
1288	30.0	14.0	14.5	17.0	18.5	5.0
1290	21.0	8.0	22.0	34.0	11.5	4.5
1291	28.0	15.5	1.7	21.5	6.5	26.5
1292	18.0	3.5	3.0	36.5	6.0	4.5
1293	33.5	17.0	10.5	23.5	8.5	7.5
1294	25.5	19.0	29.3	14.5	7.5	3.0
1295	41.5	21.0	12.5	11.5	6.0	5.5
1296	15.5	0.5	35.5	22.0	15.0	11.0
1300	62.5	4.0	14.0	11.5	3.5	4.0
1301	4.0	7.0	30.5	12.5	8.0	----
1302	13.5	1.0	36.5	28.0	16.0	7.0
1303	10.0	----	60.0	26.5	8.5	1.5
1304	15.5	17.0	18.5	33.0	12.0	1.5
1306	27.5	18.0	11.5	21.5	4.0	8.5
1307	45.5	33.0	7.5	7.0	5.0	3.5
1308	17.5	21.5	31.0	16.5	9.5	1.0
1309	20.0	17.0	30.0	16.5	12.0	4.0
1310	25.5	10.5	25.5	18.0	11.0	4.5
1311	10.5	6.5	18.5	34.5	17.5	9.5
1312	18.3	3.0	24.5	34.0	15.0	0.5
1313	45.5	5.0	35.5	8.0	6.5	0.5
1315	5.0	0.5	71.0	14.0	2.5	6.5
1316	6.7	----	74.5	13.00	5.5	0.5
1317	10.0	1.5	52.0	24.5	8.5	3.5
1318	34.0	13.5	9.5	27.0	9.0	8.5
1319	9.0	2.0	3.5	74.0	5.5	3.5
1323	36.5	23.5	6.0	22.0	3.5	2.5
1324	9.5	0.5	45.5	22.5	10.0	1.5
1325	15.0	2.0	24.0	41.5	12.5	4.0
1326	6.5	----	58.0	24.0	11.5	0.5
1327	14.0	0.5	55.0	24.0	5.0	1 5
1328	13.5	0.5	40.0	24.0	7.0	9.5
1329	5.5	18.5	17.5	29.0	8.5	21.5
1330	18.0	40.0	7.0	9.5	17.0	10.5
1331	22.5	13.5	3.0	24.0	21.5	16.0
1370	4.5	11.0	10.0	30.5	30.5	7.0
1373	27.5	28.0	2.5	30.5	2.5	10.6
1399	12.5	37.5	12.5	11.0	12.0	13.0

POINT COUNT RESULTS (Continued)

Sample no.	Pellet	Ooid	Planktonic tests	Skeletal fragments	Benthic forams	Lithic fragments
1400	26.1	3.5	35.0	15.5	14.5	6.0
1401	27.0	2.0	31.0	27.0	4.5	6.5
1402	4.0	0.5	67.0	16.5	9.5	2.0
1403	35.0	1.5	31.0	22.0	7.0	4.0
1404	20.0	32.5	31.5	8.5	3.5	2.5
1406	28.5	29.5	8.5	26.5	3.5	2.5

APPENDIX II

GRAIN SIZE RESULTS

Sample no.	% Sand	% Silt	% Clay
315	99	--	--
316	75	20	4
317	93	4	3
342	70	22	7
428	99	--	--
429	99	--	--
430	100	--	--
433	100	--	--
451	71	25	4
452	77	20	3
453	94	6	--
454	93	7	--
457	97	3	--
458	98	2	--
461	96	4	--
462	98	2	--
465	97	3	--
467	96	3	--
468	98	2	--
469	72	25	2
470	84	15	1
471	98	2	--
472	98	2	--
473	98	2	--
1251	81	5.5	13.5
1252	45	41	14
1253	55	29	16
1254	62	26	12
1255	56	29	5
1256	53	35	11
1257	66	28	6
1258	70	24	6
1259	100	--	--
1261	100	--	--
1262	59	33	8
1263	66	25	8
1264	69	22	9
1265	62	26	12
1267	14	75	11
1268	34	47	19
1269	66	24	10
1270	58	31	11
1271	72	20	8
1275	100	--	--
1279	89	8	2
1280	51	41	8
1281	60	38	1
1282	54	35	11

GRAIN SIZE RESULTS (Continued)

Sample no.	% Sand	% Silt	% Clay
1283	21	73	6
1284	11	81	8
1285	10	75	15
1286	23	66	11
1287	63	25	12
1288	71	23	6
1289	37	53	10
1290	61	34	5
1291	100	--	--
1293	80	15	5
1294	64	28	8
1295	73	19	8
1296	63	25	12
1297	24	66	10
1300	75	18	7
1301	51	40	9
1302	44	42	14
1303	16	71	13
1304	48	43	9
1306	63	32	5
1307	77	19	4
1308	30	60	10
1309	51	40	9
1310	36	54	10
1311	48	43	9
1312	59	35	6
1313	42	52	6
1315	7	85	8
1316	13	79	8
1317	28	63	9
1318	89	6	5
1322	52	40	8
1323	77	18	5
1324	18	75	7
1325	66	28	6
1326	15	78	8
1327	16	83	1
1328	38	57	5
1329	69	28	3
1330	72	22	5
1370	80	13	7
1373	95	1	4
1399	98	2	--

APPENDIX III

STATISTICAL PARAMETERS

Sample no.	Median size (phi units)	Graphic sorting coefficient (phi units)
315	1.4	0.95
316	1.7	2.10
317	1.3	1.40
342	3.2	1.70
428	1.2	0.85
429	1.9	0.65
430	0.4	0.65
436	2.3	0.95
446	2.1	0.95
448	2.6	1.80
450	2.3	0.85
452	3.4	1.10
454	3.0	1.7
456	1.4	0.95
459	1.5	1.35
460	0.7	1.45
462	1.9	0.85
465	2.1	0.95
468	2.7	1.35
469	3.2	1.40
470	2.7	1.65
471	0.9	1.15
473	2.2	1.05
1251	2.5	1.6
1252	3.6	1.6
1253	3.5	1.6
1254	3.3	1.6
1255	3.3	1.6
1256	2.8	1.5
1257	2.8	2.3
1258	2.8	2.0
1259	2.7	1.8
1261	1.1	0.9
1262	2.9	2.2
1263	3.0	1.7
1264	2.4	1.7
1265	3.2	1.7
1267	4.5	0.5
1268	4.4	1.2
1269	2.9	1.5
1270	3.8	1.6
1271	1.8	1.9
1272	3.4	1.4

STATISTICAL PARAMETERS (Continued)

Sample no.	Median size (phi units)	Graphic sorting coefficient (phi units)
1275	2.4	0.8
1279	3.0	1.2
1280	4.0	1.6
1281	3.6	1.2
1282	3.7	1.7
1283	4.6	0.7
1284	4.8	0.3
1285	4.8	0.3
1286	4.6	0.6
1287	3.0	1.7
1288	3.0	1.4
1289	4.3	0.9
1290	3.8	1.2
1291	-0.7	---
1293	3.2	1.5
1294	2.8	1.8
1295	2.5	1.1
1296	2.5	2.6
1297	4.4	0.7
1300	1.8	1.6
1301	4.0	1.5
1302	4.4	2.2
1303	4.6	0.5
1304	4.0	1.5
1305	-1.0	---
1306	3.3	1.2
1307	1.5	1.8
1308	4.4	0.8
1309	3.9	1.2
1310	4.4	1.7
1311	4.2	1.8
1312	3.2	1.9
1313	4.3	2.0
1315	4.7	0.1
1316	4.6	0.4
1317	4.5	0.9
1318	2.3	2.1
1322	3.9	2.6
1323	3.9	1.2
1324	4.5	0.5
1325	3.1	1.6
1326	4.6	0.4

STATISTICAL PARAMETERS (Continued)

Sample no.	Median size (phi units)	Graphic sorting coefficient (phi units)
1327	4.5	0.4
1328	4.3	1.5
1329	1.9	4.6
1330	1.6	2.1
1370	2.5	2.1
1373	2.7	0.8

APPENDIX IV

GLOSSARY OF TERMS

1) allochem--a collective word used to designate the particles or grains that make up the bulk of many limestones--does not include the cement or matrix (Folk, 1962)

2)* benthonic--bottom dwelling

3)* calcarenite--deposit composed of sand-size, carbonate particles, comes from Latin and means lime and sand

4)* disconformity--a break in sedimentation of greater magnitude than a diastem

5)* eustatic--pertaining to world-wide changes in sea level

6) facies--a body of sediments having a definite thickness, lithological character, stratigraphic position and areal distribution (Weller, 1960 p. 521)

7) glacio-eustatic--pertaining to the advance and retreat of the continental ice sheets and the associated effect on sea level (Fairbridge, 1961)

8)* indurated--rendered hard

9) inorganic banks--mounds or prominences that are not organically formed (Logan, 1963)

10)* lithology--formerly used to mean the study of rocks, but now used to mean the composition and texture of rocks and unconsolidated sediments

11)* lutite--rocks or unconsolidated sediments that are dominantly composed of silt-and/or clay-size particles

12) micrite--fine grained carbonate mud, individual grains are usually considered to be less than 0.03 mm in diameter (Leighton and Pendexter, 1962)

13) micritic pellet--ellipsoidal, ovoid or rod-shaped grains composed of crytostalline aragonite or micrite (defined herein)

14)* onlap--the progressive pinching out of a deposit toward the margins of a depositional basin

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*Definition in American Geological Institute "Glossary of Geology and Related Sciences" (1956).

15)* relict--representing a different set of environmental conditions

16) textural/compositional groups--groups of sediments having definite textural (in this study, relative sand, silt and clay percentages) and compositional (constituents or grain types) properties, no specific area of occurrence is required (facies may be composed of one or more textural/compositional groups)

17)* terrace--relatively flat or gently inclined surfaces, which are bounded by steeper slope on one side and some sort of escarpment on the side (after Lahee, 1916, p. 271)

18)* unconformity--a surface of erosion or nondeposition--usually the former--that separates younger strata from older rocks

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*Ibid